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The purpose of this qualitative study was to examine the experiences and practices of STEM teacher leaders in elementary schools. The characteristics of the STEM teacher leaders were studied under the Teacher Leader Model Standards (2011) framework. The Teacher Leader Model Standards included: fostering collaborative culture, assessments, professional development, improving instruction, usage of data, community and family collaboration, and advocacy. STEM teacher leader participants shared their rich experiences in each of the aforementioned leadership components. The practices of STEM teacher leaders were explored by the pedagogies with which they teach STEM: reflection, real-world, hands-on, collaboration, creativity, and inquiry. Study findings included:

1. STEM teacher leaders exhibit an affinity to STEM related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning.
2. STEM teacher leaders use integrated STEM pedagogies.
3. STEM teachers function as school leaders by modeling innovation through STEM.
4. STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches.

Keywords: STEM, STEM pedagogies, STEM challenges, teacher leadership

STEM TEACHER LEADERSHIP

by

Christy Ann Bailey

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the Faculty of The Graduate School at
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Approved by

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Committee Chair

This paper is dedicated in honor of my grandparents. They believed in me. They encouraged each endeavor that I chased. Thank you for your kindness, support, and love.

Mary Gertrude Sharpe Hines & Dr. Martin Patterson Hines

Noah Clayton McBride & Tootsie Evadell Fern Underwood McBride

APPROVAL PAGE

This dissertation, written by Christy Ann Bailey, has been approved by the following committee of the Faculty at The Graduate School at The University of North Carolina at Greensboro.

Committee Chair ______________________________

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Date of Acceptance by Committee

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Date of Final Oral Examination

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Esther 4:14—“Such a time as this”—We are charged to step up and stand out when called to do so. May this research empower school leaders, politicians, and teachers to step up regarding STEM.

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To all those future STEM teacher leaders and STEM students: Be courageous. Be bold! STEM is exciting and refreshing. I hope that you feel inspired to take a chance on STEM!

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CHAPTER I

INTRODUCTION

In 2001, National Science Foundation for Education leader Judith A. Ramaley coined the phrase STEM to represent Science, Technology, Engineering, and Math (Breiner et al., 2012; Cavanagh & Trotter, 2008). STEM is an approach to education that focuses on creative problem solving and requires students to analyze and collaborate as active participants in reaching solutions (Marshall, 2010). Students are instructed in STEM with the four subjects woven together into interdisciplinary units of real world learning (Hom, 2014).

STEM is unique as it synthesizes multiple subjects through skills such as collaboration and reflection. Teaching STEM is challenging because of the expectation that teachers must be a master of various subjects and feel confident to integrate the material (Sanders, 2009). Adding to the difficulty is that teachers may not be self-assured in each STEM subject, or they must abandon familiar teaching strategies to use newer pedagogies, such as hands-on collaborative projects instead of rote memorization (Myers & Berkowicz, 2015). These current pedagogies require STEM teachers to be unique change agents who are willing to implement new instructional strategies (Slavit et al., 2016).

The STEM teacher is not exclusive to the science or technology field. A teacher who utilizes STEM pedagogies, such as inquiry or real- world problem solving can be categorized as a STEM teacher (El Nagdi et al., 2018; Kelley & Knowles, 2016). For example, a history teacher can teach concepts through real-world community problems and empower the students to suggest solutions through collaboration and inquiry. Or, a music teacher can encourage construction of student made instruments with a hands-on approach. The reversal is also true that teachers who instruct historically STEM subjects, like science, are not automatically considered STEM teachers. Teachers who apply STEM pedagogies and integrate STEM subject matter could be considered a STEM teacher (El Nagdi et al., 2018; Kelley & Knowles, 2016).

Introduction to STEM

STEM is considered to be useful to combat descending test scores. Students across the United States have produced declining test scores in math and science (Desilver, 2017; Heitin, 2013). The latest Programme for International Student Assessment (PISA, 2018) reveals the United States ranks 36th out of 79 counties in Math and 18th out of 79 countries in Science, behind many advanced nations, including Singapore, Japan, and the United Kingdom (Barshay, 2019). The National Assessment of Education Process (NAEP) scores in 2015 revealed that Math scores are in continual decline in 4th and 8th grade students and hit the greatest low point since 1990 (Desilver, 2017). The 2019 NAEP Fall scores reveal no significant change with Math 4th grade scores increased by one point and Math 8th grade scores decreased by one point (The Nation's Report Card, 2019). The 2018 ACT report revealed that Math scores were at a 20-year low (Learning Liftoff, 2019). The National Council of Teachers of Mathematics (NCTM) suggests that scores are plummeting because of broad expectations concerning topics covered at a surface level (NCTM, 2018). Additionally, the public has begun to convey its dissatisfaction with science and math scores with only 29% of the participants in a PEW Research Center report ranking the K-12 STEM education at above average (Desilver, 2017). This puts more pressure on the public opinion of STEM's model of active learning teaching to salvage schools’ math and science test scores (Freeman et al., 2014). STEM can be leveraged as support for hooking student interest in the fields of math and science, where test scores are dipping.

There is an urgency to have STEM teacher leaders to prepare our students. It is important for STEM to be emphasized in schools due to the 14% expected increase in new jobs that require STEM skills, compared to 9% growth of non-STEM jobs (Education Commission of the States, 2019). Another incentive for STEM growth is the median hourly pay, which for STEM jobs is $38, compared to $19 for non-STEM occupations (U.S. Bureau of Labor Statistics, 2017). There is a growing need for companies to fill STEM jobs, and businesses with a majority of STEM workers translates to higher salaries (Fayer et al., 2017). STEM workers make an average of 24% more than their non-STEM peers who are similarly educated (Graf et al., 2018).

All evidence concludes that the future of industry will revolve around STEM careers (Graf et al., 2018). Understanding how school leaders support STEM-related education efforts and build student interest in STEM will strengthen STEM practices, which are foundational in best education procedures. Research supports STEM as a necessity in schools because of a dearth of upcoming, highly sought-after and well-paid career opportunities (Education Commission of the States, 2019; Graf et al., 2018).

STEM education can lay a foundation for a huge impact through supporting students to become prepared in STEM jobs and lucrative salaries.

Purpose of the Study

There is a paucity of literature about how teacher leaders become involved in STEM and how they use STEM in their schools. The purpose of this study is to understand how elementary school teachers attempt to serve as STEM teacher leaders and how the Teacher Leader Model Standards are reflected in STEM teacher practice. Teacher leadership refers to the sphere of influence teachers use to positively support their school community with the goal of student growth (York-Barr and Duke, 2004).

Understanding the influences and experiences that spark a passion for a teacher leader to promote STEM is critical for knowing how to nurture and encourage other STEM leaders. STEM influences could include important figures in their lives who exemplified STEM teaching and learning such as, mentors and teachers; as well as, including participation in activities such as 4-H, camping, or scouting. I want to make connections about what launched a teacher's interest in STEM, so we can support future STEM teacher leaders. Discerning what the best practices of STEM teacher leaders is meaningful for encouraging new STEM teacher leaders. Currently, the literature reflects that STEM is important, but it does not explain how educators arrive prepared for STEM (Graf et al., 2018). Thus, the purpose of this study is to identify and gain insight into the practices of STEM leaders in education through examining pathways and STEM practices.

Background: What is STEM?

Teaching science and math has changed over the course of education in the United States. The Morrill Act of 1862 and the Industrial Revolution started interest in educating students for STEM, but the big push came after World War II (Bowden, 1975). There was a huge fascination in aviation innovations, which grew when the Wright Brothers achieved their first flight in 1903 (Johnson, 2019). World War 1 heightened the change from trench warfare to supporting aviation inventions through aerial mapping and message streamers (Keitch & Blair, 2017). During World War I improvements with submarines (Karau, 2017) increased consistent use of chemical warfare (Fitzgerald, 2008), gas masks (Trueman, 2015), early machine guns (Kelley, 2010), and the introduction of tanks (Trueman, 2015) all included scientific discoveries that focused on war efforts.

Most notably, the focus on winning World War II put a spotlight on engineers and scientists. The race was led by scientists pushing to end the war through inventing various land and water vehicles—as well as the atomic bomb (White, 2014). World War II became an outlet for scientists to develop mustard gas antidotes, penicillin, food conservation techniques, animal genetics gene research methods (Pringle & Peters, 1975), rockets, nuclear technology, efficiency of air travel speed, Teflon, and solid-state electronics (Bowden, 1975; Davies & Stammers, 1975). A common belief was that science would win the war, and many would say that it did (Pringle & Peters, 1975). There was little money for science research, so the Armed Forces began to financially support scientific endeavors that were connected to the defense of the United States (Bowden, 1975).

Following World War II, in 1957 Russia released Sputnik, which shocked the United States and created a frenzy in ramping up science and math education (Bowden, 1975; Myers & Berkowicz, 2015; Powell, 2007). “Decades after Sputnik burned into the atmosphere, we are still talking about science education, as a means of security” (Powell, 2007, para. 9). The post-Sputnik era created an elitist view of education with only the top-achieving students being offered high level courses and accelerated learning (Herold, 1974).

Succeeding this era into the 1980s, *A Nation at Risk* was released, and its launch increased intensity in math and science courses as a fight against mediocrity (Park, 2004). Educational departments that addressed STEM topics had not been identified with a specific term at that time. These historical happenings set the stage for our current STEM education as STEM changes from a necessity for war and industry and shifts into an educational strength that increases productivity and produces high-paying jobs.

STEM initiatives were heightened to support war efforts; however, there are other great reasons to teach with STEM. STEM jobs and healthcare field needs are expected to continue to grow above the average rate of all other jobs (Bureau of Labor Statistics 2019). Outside of STEM specific jobs, students will need evidence gathering, analytical, and collaboration skills to persevere with complex challenges in all jobs (US Department of Education, 2020). The “T” in STEM for technology has grown as an integral part of everyday life and students will need to have strong digital literacy skills to become technologically proficient (Milcrom-Elcott, 2020). STEM teacher leaders are needed to prepare students for these necessary STEM skills.

STEM Definition

STEM is an acronym that represents **S**cience, **T**echnology, **E**ngineering, and **M**ath. Many experts agree that STEM is "'laboratory-based,' 'inquiry-based,' 'integrative,' 'mosaic understanding,' 'conceptual, thematic metacognitive,' and 'student-centered work'" (Wee Teo, 2012, p. 667). I choose to define STEM as creatively and collaboratively solving real world problems in order to become a critical thinker.

Even though Sputnik, World War II, and *A Nation at Risk* created a strong interest in math and science, it was not until the 2000s that the term STEM was coined (Cavanagh & Trotter, 2008). Since STEM has been established, it has been deliberately transitioned into schools. STEM's best practices focus on using inquiry methods to explore core concepts. STEM education requires students to problem-solve and think outside the box with a focus on critically analyzing, thinking creatively, and collaborating (Marshall, 2010). It is suggested through the literature that STEM is continuously changing as we learn what is needed for all students to be successful globally. The literature sparked my interest in identifying the experiences and practices of STEM teacher leaders, as this is notably missing from recent research.

STEM in the 21st Century

STEM is much more evolved than the subjects of science and math. It is a pedagogical approach to teaching those subjects with a focus on inquiry-based learning. "Inquiry is a method of learning in which students are encouraged to ask questions about things, pursue the answers themselves, and then use the answers as a starting point for further study" (Pierpont, 2005, p. 38). Inquiry has multiple definitions, but for the purpose of this research, "science inquiry [is the] search for evidence in order to make and revise explanations based on the evidence found and through critical and logical thinking" (Haug, 2014, p. 79). Through inquiry, students are encouraged to forge new paths and allowed to be curious enough to create a zest for learning. "Experts agree that inquiry is a great approach for teaching science" (Haug, 2014, p. 79), and embedding the STEM topics with project-based learning and rigorous application creates a unique, hands-on learning process.

STEAM

One of the most recent STEM debates is about adding an "A" for the arts to create STEAM. The artistic design process includes creativity in research and developing a prototype, much like the engineering design (Bequette, 2012). Creating an interdisciplinary platform for the arts and sciences to coexist will enable students to interconnect the design process through aesthetic inquiry. "There is a new culture forming in which art, science, and technology are inseparable. Artists are using digital media, art with coding, developed algorithms and equations" (Myers & Berkowicz, 2015, p. 3).

STEAM can be a solution for students who need stimulation, creativity, and inquiry in order to problem-solve (Wynn & Harris, 2012). Bequette (2012) illustrates through the description of artistic design that students define problems, balance challenges/benefits, create a prototype, and then present it to be tested. Several hybrid art/science creators, such as Nathalie Miebach, use STEM skills as she weaves baskets for explorations that can interpret astronomical data (Bequette, 2012). This shows the connection between art and science for students. “Artists (visual thinkers) can benefit by learning how scientists and mathematicians think and test their thoughts. Likewise, science and math students will advance by understanding how artists think and execute ideas” (Wynn & Harris, 2012, p. 43). Art can be used as a medium to create interdisciplinary links between subjects, as students can create a visual representation of the conservation and interdependence of the local natural resources (Wynn & Harris, 2012).

Interdisciplinary Approach

Research supports that STEM subjects should be integrated when taught (Shernoff et al., 2017; Sujeewa Vijayanthi Polgampala et al., 2017). An expansive, all-embracing method is to teach all four STEM areas by fusing them together (Dugger, 2010). For example, a math teacher would create interaction by teaching math through science, technology, and engineering lesson activities. Another definition explains that an integrated approach examines a STEM subject along with another school topic, and students learn them both together (Sanders, 2009). As for instructing teachers in STEM, the main function is “focused on discerning key recommendations for creating meaningful and sustainable interdisciplinary learning environments in STEM” (Elrod, 2010, p. 26). The integration of STEM content requires attention from two or more STEM categories to make each content more relevant (Thibaut et al., 2018). The interdisciplinary approach often used starts with a problem that focuses on critical thinking instead of a subject and requires students to use problem solving skills to reach a desired solution (Thibaut et al., 2018). Researchers describe the integration of STEM education to include instructional design, educator support, and adjustments to the learning environment (Shernoff et al., 2017). Integrated lessons become exciting with applications in multiple subjects, critical thinking, and creativity (Shernoff et al., 2017) and promote solutions to 21st century challenges like health care and environmental concerns (Bybee, 2010; Kelley & Knowles, 2016).

Integrated approaches may also include connections to STEM careers, cognitive tasks, and creating evidence based “explanations” (Shernoff et al., 2017). STEM integration supports learning between the subjects and helps explain how the subjects harmonize each topic (Myers & Berkowicz, 2015). “Engineering can be a motivator as a natural way to learn to integrate STEM concepts, because real world engineering problems are often complex and require the application of mathematics and science” (Shernoff et al., 2017, p. 17). For example, designing a treehouse would require students to use engineering to consider scientific and environmental factors, such as tree species and soil composition, as well as mathematical concerns such as the dimensions of the house and individual measurements. “Think of STEM as one subject, innovation, that requires students to engage with problem solving with rigorous math, science, inquiry, and problem solving skills” (Shernoff et al., 2017, p. 1).

STEM Practices

Research supports best practices in STEM classrooms. Literature seems to be lacking in demonstrating the commitment of teacher leaders to STEM. Only the most recent graduates would have received STEM training in their college programming (Dailey et al., 2015). For example, North Carolina State University, located in Raleigh, North Carolina, launched its STEM Education program in 2014-2015 as the first program of its kind in the state.

The literature suggests that STEM has shifted in its approach and implications since being introduced in American schools. The STEM concepts have transformed from being agricultural- or apprentice-based to an intensive science push, integrating concepts of creating and analyzing (Gunn et al., 2017). One pathway to approach STEM is the silo approach, which is to teach each subject individually, with little interdisciplinary study (Dugger, 2010). For example, schools may decide to keep math math separate from technology or science integration. Many schools have used a pedagogical theme of problem-based learning that connects the independent content areas and pulls them together as an interdisciplinary approach (Gunn et al., 2017). There is debate as to whether to integrate STEM topics or keep them separated into isolated, focused subjects (Shernoff et al., 2017). Some schools have created a stronger priority over a particular subject, shown in capital letters, like SteM or sTEm (Dugger, 2010). Another possibility is a focus on the medical field, by adding another “M” to make STEMM (Bequette, 2012; Berk et al., 2014).

Recent STEM research has identified lenses that examine how to successfully teach STEM, including personalized learning and technical career skills (LaForce et al., 2016). Researchers voice concern that when STEM is integrated into one or more subjects, one subject may become under-emphasized or left out (Asunda & Mativio, 2015/2016). As more states adopt the Next Generation Science Standards (NGSS), science education will expand with an emphasis on the integration of the STEM subjects through engineering (Moore & Smith, 2014). Currently, as students are called to be global problem solvers tackling topics such as climate change concerns and resource sustainability, the need to integrate STEM topics across multiple disciplines and use a NGSS engineering lens to problem solve has become a theme of clarity for integration (Kelley & Knowles, 2016; Shernoff et al., 2017). What is currently needed is an understanding of how committed STEM teacher leaders inspire students to become problem solvers and work towards rigorous standards, like NGSS.

STEM Teachers

Many scholars agree that STEM teachers possess a complex variety of skill sets. STEM teachers are unique in that they are held to the expectation of teaching subjects in which they might not be experts (Sanders, 2009; Stains et al., 2018). STEM teachers are shifting their implementation of content strategies to teach in ways that are different than they were taught, primarily the shift is from direct instruction to inquiry-based learning (Kelley & Knowles, 2016; Myers & Berkowicz, 2015). A study of the complex role of STEM teachers revealed that they are learners, risk-takers, inquirers, curriculum design negotiators, and collaborators (Slavit et al., 2016).

A STEM teacher is a learner as s/he collaborates with other teachers, completes learning trials, and constructs new problem-solving challenges for students (Myers & Berkowicz, 2015). Kennedy and Odell’s (2014) research suggests that STEM teacher leaders integrate STEM instructional practices (e.g., inquiry methods, collaboration, and real-world problem solving), seek quality professional development, locate and use quality STEM resources, and connect stakeholders to school STEM efforts (Kennedy & Odell, 2014). STEM teachers are open to change, see failure as opportunity, and believe in the need for inclusive and equitable learning for all students (El Nagdi et al., 2018).

STEM teacher leaders must build curriculum where it does not exist (Guzey, Moore, & Harwell, 2016), integrate STEM topics (Kelley & Knowles, 2016), and encourage other teachers to become learners as well (El Nagdi et al., 2018). Indeed, the STEM teacher is imperative for STEM program success, "A dynamic teacher with a positive attitude toward STEM seems to be the single most important factor to implementation fidelity and STEM program success" (Margot & Kettler, 2019, p. 11). STEM teachers are the tipping point in growing STEM education for our students.

The discipline a teacher teaches does not dictate whether or not a teacher is a STEM leader. A STEM teacher is one who uses inquiry, collaboration, and real-world problem solving with the use of nonfiction texts, experimental trials, and creative lessons (El Nagdi et al., 2018; Kelley & Knowles, 2016). For this STEM teacher leader study, I am referring to the leadership definition crafted by York-Barr and Duke (2004): Teacher leadership is "the process by which teachers individually or collectively, influence their colleagues, principals, and other members of school communities to improve teaching and learning practices with the aim of increased student learning and achievement" (pp. 287–288). A teacher can teach a STEM subject but not necessarily be a STEM teacher. Conversely, a teacher can teach a non-STEM subject and be a STEM teacher. For example, an English teacher can teach reading strategies through the use of nonfiction science texts supported with hands-on experimental trials, for example, water tension of pennies with different types of liquid. This English teacher is a STEM teacher. There could also be a science teacher who teaches only with direct instruction and noticeably absent from the classroom is collaboration or real-world problem solving. This science teacher is not likely a STEM teacher.

STEM Teachers and Equity

Recent research explains that STEM teachers have the belief that every student has the ability to learn and that STEM education bridges achievement gaps and engages students (El Nagdi et al., 2018). Research also acknowledges the need for more STEM equity studies and the need to strategically align STEM subjects and schools towards diverse populations (Slavit et al., 2016). Administrators polled rated STEM equity as very important but also reported action steps towards supporting it occurring at a low frequency (Forman et al., 2015). STEM education used to support underrepresented groups occurs by promoting diverse students to complete STEM internships and meet with research advisors (Forman et al., 2015). Myers and Berkowitz (2015) state,

> No longer can any student or group of students be excluded from access to this type of education. It is for all students . . . The perception about the difficulty of learning science, technology, engineering, and math may have contributed to a reticence, pointing students with learning challenges away from the path that includes these subjects. Hence, we have excluded an entire population of students from being prepared for further education or employment in STEM fields. (p. 29)

Technology has become an incredible tool for removing barriers towards STEM (Myers & Berkowicz, 2015). STEM education must look for innovative ways to become inclusive with opportunities for all students (Peters-Burton & Johnson, 2018). STEM, as a systematic shift, provides an environment in which all children will have sense-making and knowledge -building opportunities as they construct, investigate, imagine, and create (Myers & Berkowicz, 2015). The need is critical for STEM teachers who believe that ALL learners should be given the opportunity to solve real world problems and understand that special needs students may necessitate the use of creative teaching (Myers & Berkowicz, 2015). It is crucial that all STEM teacher leaders believe that all students should be included in STEM instruction.

STEM with the arts (STEAM) can be a powerful tool to make STEM accessible to students of all learning levels. Integrating arts with STEM can benefit diverse populations because “. . . the arts can stimulate student's motivation in pursuing difficult topics in STEM” (Hwang & Taylor, 2016, p. 42). Using the arts allows students to be creative and utilize unexpected mediums to solve, which can be helpful when working with students with disabilities. For example, Hwang and Taylor (2016) stated,

> As emphasis is placed on STEM education as a means for future success, the needs of students with disabilities need to be considered . . . by integrating the arts in STEM education, thereby transforming it to STEAM, students with disabilities are granted increased access to STEM success. (p. 44)

Elements that include positive STEM impacts for equity are parental involvement, bilingual education, and early exposure to STEM fields and careers (Kennedy & Odell, 2014). Using a problem-solving framework with STEM allows students with disabilities to become integrated with authentic, real world experiences (Hwang & Taylor, 2016). STEM can help close the achievement gap, especially if students are targeted for support in elementary schools (Myers & Berkowicz, 2015).

Research indicates an equity imbalance in STEM throughout both schools and the workforce. The purpose of this study is to better understand the experiences and practices of STEM teacher leaders. Most of the available research explains how critical it is to provide STEM opportunities for marginalized groups, such as women, students of color, and students with disabilities. There remains a void in teacher preparation programs to prepare for STEM, while universities are expanding to add teacher STEM endorsements (Dailey et al., 2015). It is important to understand what happens between childhood and adulthood to stimulate a teacher's interest in becoming a STEM teacher and carrying this spark into the classroom.

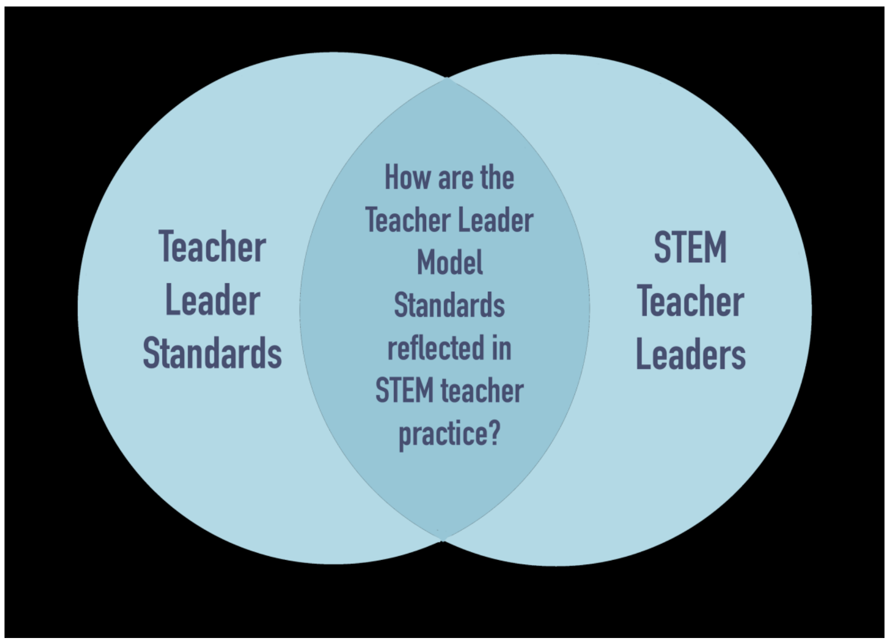
Conceptual Framework: Teacher Leadership

In this research, I used the Teacher Leader Model Standards (Teacher Leadership Exploratory Consortium [TLEC], 2011) as a conceptual framework for the elements of describing a STEM teacher leader. The Teacher Leader Model Standards (TLEC, 2011) include characteristics that describe teacher leaders. Chapter II discusses the TLMS and their application to the examination and analysis of committed STEM teacher leaders' practice. The TLMS describe the powerful role teachers play in supporting student success through the standards. TLMS include collaboration, research, professional development, facilitating improvements, data usage, family and community outreach, and advocating for students. Each strand of the TLMS supports teachers' efforts in developing different components of leadership to grow themselves professionally and foster school growth. Teacher leaders may be informal or formal; both cultivate school culture, support principals, and enhance education of the students (TLEC, 2011).

The conceptual framework guides both the research questions and the interview questions. The TLMS model identifies what exemplary teacher leaders' practices are and through this lens, I studied STEM teacher leaders' practices.

Figure 1

STEM Teacher Leader Model. Researching the Space Where the TLMS Meet and They are Reflected in STEM Teacher Practice.



Research Questions

The lack of understanding of STEM teacher leadership and what constitutes best practices requires further research. STEM teacher leadership includes classroom teachers, curriculum facilitators, and other teachers who currently use STEM in their schools. The research participants included a committed group of STEM teacher leaders. Thus, this qualitative research study sought to craft a better understanding of this over-arching research question:

What are the experiences and practices of STEM Teacher Leaders?

Two focus questions further define the study:

- How are the practices of STEM teacher leaders reflected in the Teacher Leader Model Standards?
- How do STEM teacher leaders instructionally enact the pedagogical practices of creativity, collaboration, inquiry through real world problem-solving, and reflection in classrooms and schools?

Methodology Overview

This research study was conducted with elementary teachers who are committed to using STEM. For the purpose of this study, committed STEM teacher leaders include individuals who currently use STEM strategies to reach academic goals. STEM teacher leaders were selected based on district office recommendations about their local public school teachers. District office staff members, including a Curriculum and Instruction assistant superintendent; Elementary director; Academically Gifted Lead; and Director of Digital Learning replied to a request to suggest possible participants. Participants were selected based on whether they taught in the local public school, they had an interest in STEM, and they endeavored to use STEM practices regularly in their classes. Participants who were chosen completed individual interviews that gathered details to explain their pathways and best practices.

This qualitative research consisted of 60- to 90-minute individual interviews with 10 committed STEM teacher leaders. I audio recorded and transcribed these semi-structured interviews. Follow up occurred with member checks of transcriptions to verify the collected information. Descriptions were shared in the following chapters.

Summary

I have personal and professional goals for this STEM teacher leadership study. Personally, I want to learn everything I can about supporting STEM, because I wish that when I was a student, my teachers had used STEM best practices. Science was a high interest topic to me, but it felt dulled down as it was rote instructed. Professionally, as an administrator, I want to understand the support needed to encourage STEM teacher leaders.

In Chapter I, I explored the definition of STEM as an acronym that represents Science, Technology, Engineering, and Math. Researchers explain that STEM is an inquiry-based method of putting the students in the center of learning through creative real-world problem solving (Wee Teo, 2012). In the United States, math and science test scores have been in decline (Desilver, 2017). There is an urgency to prepare our students for high paying STEM jobs. The Teacher Leader Model Standards (Teacher Leadership Exploratory Consortium, 2011) conceptual framework seeks to describe elements of a teacher leader.

In Chapter II, I review the literature to explain STEM elements, STEM experiences, STEM influencers, qualities of teacher leaders, and STEM practices. Chapter II concludes with the limitations of the research available and the theoretical framework to be used for this study. Chapter III analyzes the research methods, selection of participants, research design, data collection, and analysis. Chapter IV reveals the participants' voices and stories through themes. Finally, Chapter V revisits the research questions and offers recommendations for further study. Through this qualitative study, the in-depth interviews explore the experiences and practices of STEM teacher leaders.

CHAPTER II

LITERATURE REVIEW

The majority of the current STEM research focuses on STEM and test scores, STEM marginalized groups, or buzzworthy pieces about beginning a STEM program. There are limited publications that mention STEM teacher leaders. Specifically, Myers and Berkowicz's (2015) guidebook for STEM school leaders and an assortment of scholarly articles stand out in the narrow availability of STEM leadership texts. Divergence exists in STEM teacher leaders in what pathways led them to STEM and describing their best STEM practices. The School Teacher Leader Model Standards is the conceptual framework for this study. Notably absent from STEM research are

- STEM teacher leader identity (Kelley & Knowles, 2016; El Nagdi et al., 2018),
- Teachers creating STEM curriculum (Slavit et al., 2016),
- Factors in implementing STEM schools (Forman et al., 2015),
- STEM for students with disabilities (Hwang & Taylor, 2016), STEM equity (Kelley & Knowles, 2016), and
- Integrated STEM education and how it promotes high level learning (Kelley & Knowles, 2016).

Research on STEM teachers is necessary to better understand teachers' roles in implementing STEM curriculum and teacher identities (El Nagdi et al., 2018; Guzey, Moore, & Harwell, 2016). In 2019, I used ERIC within the UNCG database with these keywords: “STEM,” “Teacher,” and “Leadership,” with a set time from 2009-2019, and this yielded 249 studies. Then I excluded all the studies about the workforce, stem cell research, Race to the Top, or vital signs studies, and I located 12 studies that were related to my research.

STEM Practice

Effective practices for STEM teachers include creativity, collaboration, inquiry through real world problems, and reflection. Educators should incorporate collaboration into lessons, which would include creativity, critical thinking, and communication (Zimmerman, 2018). The best practice of a STEM leader revolves around the instructional use of inquiry methods (Cooper & Heaverlo, 2013). These instructional practices with STEM also promote real world applications for students with as many hands-on opportunities as possible (Lynch, 2017).

Creativity

Creativity is discussed as a necessary skill to respond in STEM learning, but teachers cite lack of professional development in how to integrate it (Hanif, Wijawa, & Winarno, 2019). Teachers who use open-ended questions and allow students to formulate responsive solutions foster creativity (Jolly, 2013). Recent studies identify STEM creativity into the following categories: adventurous, curiosity, imagination, and challenge as each is at work while students investigate and seek STEM solutions (Hanif, Wijawa, & Winarno, 2019). Students cannot rely on the correct answer or use a Google search, when there are multiple pathways to reach solutions. There is an art to inspiring students into discovering the “why” or “how” something works. The use of creativity promotes students and teachers to integrate multiple subjects and blur the lines between them and produce unexpected solutions (Henreriksen, 2014). Crafting lessons where students are forced to dive deeper into understanding piques a natural curiosity (Jolly, 2013). Research supports that creativity breaks the ice and allows students to play with topics in order to become comfortable and create higher understanding (Ramirez, 2013). Teachers who enrich their lessons with creativity have highly engaged students and deeper experiences with STEM teaching principles and enhance the disciplinary knowledge in multiple topics (Henriksen, 2014). Recent research has shown that using a creativity-based science approach has strengthened student’s engagement and excitement about STEM topics and has concluded with a measurable impact of increased test scores (Henriksen, 2014).

Collaboration

STEM collaboration allows students to establish communication skills through presenting, sharing ideas, and analyzing differences (Sahin et al., 2014). Collaboration is critical in STEM learning because it combines students’ strengths and multiple perspectives (Yuen et al., 2014). The World Economic Forum Future of Jobs reports that collaboration will be one of the top five most important job skills by 2020 (Schwantes, 2017). Students need to learn to communicate their thinking and complete challenges as a part of a team, similar to real world opportunities. Through collaboration, students learn to ask questions in order to gain a better understanding of conflicts and dissolve issues in a controlled environment with positive support (Sahin et al., 2014). Setting a clear purpose for collaboration and agreeing on vocabulary supports transparency for the collaboration (Tran, 2015). Learning to collaborate builds confidence in the classroom with positive peer interactions and in daily social discussions (Sahin et al., 2014) as well as a higher sense of self efficacy with the content knowledge (Yuen et al., 2014). Collaboration through building trust and learning to reach a group consensus prepares students for STEM and for other academic challenges (Tran, 2015).

Inquiry

Inquiry promotes the use of hands-on activities to intentionally test ideas (Thibaut et al., 2018). Utilizing an inquiry teaching method promotes the students working as scientists to formulate hypotheses and complete experiments (Kelley & Knowles, 2016). Students are naturally curious, which leads them to want to explore for answers (Sujeewa Vijayanthi Polgampala et al., 2017). Inquiry allows questioning to be important (Thibaut et al., 2018) and for students to be in charge of their education (Kelley & Knowles, 2016). “Students are encouraged to test their existing ideas by taking things apart, making predictions, observing, and recording their explanations” (Thibaut et al., 2018, p. 6). Teachers may hesitate to include inquiry methods because they fear they are ill-equipped to explain scientific research and experiments that may falter (Kelley & Knowles, 2016).

Real-World Applications

Providing materials for actual experiments is much more meaningful for student learning than the old-fashioned belief of a teacher as a ‘sage on the stage’ (Jolly, 2013). “Students seek explanations about the natural world to improve the built world” (Shernoff et al., 2017, p. 15). Permitting time to play with materials, getting their hands dirty, and exploring allows students to become comfortable (Ramirez, 2013). Starting instruction with a mystery or a problem for students to investigate, creates a hook onto scientific learning (Jolly, 2013). Granting students time and resources to investigate real world environmental or economic problems promotes the student to be in the driver's seat seeking solutions (Jolly, 2014). An example could be problem solving the eelgrass loss of habitat and the effects on the Chesapeake Bay estuary. This affects everything on the Bay; from the pollution levels, soil erosion, water play, fishing, and seafood that is farmed there. Propelling students to become real world problem solvers, allows them training to become critical thinkers and make the world a better place (Cooper & Heaverlo, 2013; Haug, 2014). Committed STEM teacher leaders create opportunities for their students to connect to the world around them and improve lives.

Another example is project-based learning (PBL) in which students are provided with the end result and teachers assist as they make progress towards their goal (Thibaut et al., 2018). With this approach a teacher’s role is that of a resource (Shernoff et al., 2017). PBL is intricate and not clear cut. PBLs may offer extra information that students have to wade through in order to collect what is necessary to solve the problem, which is what happens to real life scientists and engineers (Haug, 2014; Thibaut et al., 2018). The paradigm shift has occurred; teachers are no longer class authoritarians but must be prepared to facilitate experiences for students and share the knowledge (Ejiwale, 2012).

Reflection—Growth from Failure

Reflection on successes and pitfalls allows a teacher leader to be equipped for classroom challenges. An unavoidable part of being a STEM educator is failure. How the teacher leader accepts failure as a necessary growing pain to moving forward shows grit in a STEM teacher and student. Failure and reflection teach students that it is acceptable to take risks, and experiments are practice to see what works (Jolly, 2013). As students learn that some options do not work, they will discover that STEM allows for multiple pathways to find the answer. This may require many teachers to reframe what they accept as the right answer. Because reflection is so important when testing hypotheses, it is part of the process to discuss failures, challenges, and successes. Jolly (2014) states,

> When designing and testing prototypes, teams may flounder and fail to solve the problem. That’s okay. They are expected to learn from what went wrong, and try again. Failure is considered a positive step on the way to discovering and designing solutions. (para. 17)

“This revision step is an important part of STEM because it requires perseverance and the acknowledgment that solutions can always be improved upon. There is more than one answer to STEM challenges” (Margot & Kettler, 2019, p. 2). Failure in STEM is a necessary part of finding what doesn’t work so the student can discover more possible solutions. Failures are possible and sometimes painful, but without them STEM learners and teachers could miss fundamental values that are advantageous (Brubaker & Coble, 2005).

STEM is messy, exciting, and challenging. It might not work every time. There is not a blueprint that is foolproof. Margot and Kettler (2019) state,

> STEM teacher leaders need to be confident enough to know that some things will fail—they need to have the attitude to respond, laugh, and pick up the pieces to try again. Teachers believe that struggle and even failure are inherent yet valuable components of the engineering design process within STEM education. Students

> are asked to improve upon their designs and solutions. They are encouraged to take risks. Teachers feel this benefit is special to students, especially high-achieving students that typically do not reach a point of frustration in their classrooms. Because failure is part of the process, it is expected and therefore accepted. This encourages students to do things they do not know how to do and challenge themselves to confront failure. (p. 10)

Reflective practitioners consider evaluation entry points, expectations, and support to make a lesson stronger. Reflection lets teachers and students pause the momentum to check for understanding, assess possible changes, and predict how they would proceed in the future (Ring et al., 2017). Reflection is also a time for owning the learning and committing to what you need to know next. It is an incredible growth tool for STEM teacher leaders to use reflection to consider expectations and possible outcomes with lesson experiences. Reflection is key for a committed STEM teacher leader in responding to the inevitable failures and moving forward.

Educator Practice in STEM

STEM education has become an expectation in many schools; however, many teachers are not confident on how to implement STEM into their classrooms (Kelley & Knowles, 2016). Teaching through integrated STEM approaches is new and challenging to teachers who are expected to teach multiple subjects, including those outside of their fields of expertise (Guzey, Moore, & Harwell, 2016; Guzey, Moore, Harwell, & Moreno, 2016; Stains et al., 2018). STEM teachers need specific professional development, or they will continue to teach in the way they were taught (Myers & Berkowicz, 2015). There are specific challenges that keep teachers from using STEM. Pedagogical challenges include teachers being unsure of how to provide high quality content (Stains et al., 2018). Curriculum difficulties could include absence of materials, lack of confidence in subject matter, or inadequate teaching time (Kelley & Knowles, 2016). Limited professional development and college teacher opportunities leave teachers feeling unprepared to tackle STEM lessons in their classrooms (Margot & Kettler, 2019).

Pedagogical Challenges

Teachers may struggle to produce quality content while connecting the high-level achievement STEM targets (Kelley & Knowles, 2016; Slavit et al., 2016). Teachers are challenged to craft lessons that show STEM's integrated goals without proper professional development, and support can fall short with condensed basic lessons (El Nagdi et al., 2018). Shifting from teacher-led instruction to student-led instruction while integrating curriculum K-12 with an engineering theme can also be difficult for teachers (Guzey, Moore, & Harwell, 2016; Margot & Kettler, 2019). Additionally, using STEM pedagogy to craft lessons that are inclusive towards students with disabilities can be challenging for staff (Margot & Kettler, 2019). STEM teacher leaders must overcome these pedagogical challenges to provide engaging STEM lessons that meet high expectations.

Curricular Challenges

STEM teachers must overcome difficulties, such as limited professional development with integration of STEM and curriculum shortcomings (Ejiwale, 2012). Teachers may stumble as they learn to organize curriculum and instruction so that the integration assimilates seamlessly (Guzey, Moore, & Harwell, 2016). Locating high quality materials that are ready for integration can be a great difficulty (Guzey, Moore &

Harwell, 2016; Margot & Kettler, 2019). More physical science topics are connected to STEM, so teachers of earth and life sciences have a greater frustration to design STEM activities (Guzey, Moore, & Harwell, 2016). Teachers may become concerned about forcing a STEM curriculum into an already fully loaded content specific curriculum (Margot & Kettler, 2019) and the stress of testing pressures (Isabelle, 2017).

Teacher Supports

STEM teachers have anxiety about trying new things without permission and often feel pressure to collaborate with staff, but this can be complicated with fixed class schedules (Margot & Kettler, 2019; Slavit et al., 2016). At times, teachers may have a negative attitude towards STEM, which results in avoidance of teaching with STEM (Appleton, 2013). “Misconceptions about STEM may hold back the capacity for shifting the local educational system into one designed to better prepare students for the world in which they live” (Myers & Berkowicz, 2015, p. 36). However, to overcome their apprehension, teachers can request ready-made STEM lesson plans and meaningful professional development to support them with integrated STEM (Margot & Ketter, 2019). STEM professional development is a critical need beyond one-time exposure; teachers desire hands-on teaching support to practice implementing what teachers have been taught (Patton, 2020). STEM is complex with challenges, but it will be rewarding to the teachers with successful knowledge on how to solve real world problems through the use of engineering (Guzey, Moore, Harwell, & Moreno, 2016).

STEM College Preparation

The goal is to have well qualified teachers excited about teaching in STEM subjects who are dedicated to mastering both topics and STEM pedagogy courses (Gillespie, 2015). First-rate teacher preparation programs are vital when recruiting accomplished teachers to fill the STEM teacher voids (Ejiwale, 2012). The bulk of elementary education graduates have had minimum math courses and little training in mathematical reasoning and problem solving—essential topics in STEM (Myers & Berkowicz, 2015). Therefore, teachers who feel ill-prepared can pass their lack of confidence as anxiety to their students (Ejiwale, 2012). Currently, STEM teachers have struggles when they have received poor quality training or have not developed an affinity of affirmation between STEM topics and high student achievement (Ejiwale, 2012). Education needs to commit to recruiting the brightest students to retain them for STEM leadership for a mutually rewarding experience (Gillespie, 2015).

STEM Leadership

A STEM Teacher Leader is defined as a risk-taker and edge-walker who takes bold steps towards creating a new educational system (Myers & Berkowicz, 2015). Teacher leaders are disadvantaged because many teacher education programs fail to satisfactorily prepare them to be STEM leaders (Avendano et al., 2019). STEM teacher leaders are expected to be proficient in pedagogical content but also STEM subject knowledge, and they must have an awareness of how to craft lessons which integrate all of these together simultaneously (Avendano et al., 2019). This is quite a large task, which makes me curious about STEM teacher leader experiences and practices.

Pathways of a Committed STEM Leader

Experiences and events shape our beliefs, attitudes, and values. Digging deeper to look for similarities, patterns, and personal stories assists in creating the bigger picture of what leads to developing into a committed STEM leader. These experiences provide an opportunity to establish a backstory that connects leaders' pleasant memories to activities or events that have a science theme, i.e., camping, fishing, or lacrosse. Positive experiences, events, or mentors create a shared affinity to deepen the connection between an activity and a subject. Participating in extracurricular activities promotes a positive impact on individuals 'attitudes toward science. Thus, the pathways of a committed STEM leader may have begun with an experience that would connect the teacher to a STEM subject.

As children, many teachers were involved in after school clubs that provided a catalyst for exploring STEM topics. Girl Scouts/Boy Scouts, 4-H, summer camp, or other clubs provide experiences for students to explore and practice problem solving in the real world (Krishnamurthi et al., 2013). Research states that after school programs have put the fun into many science themed clubs as well as allowing opportunities for leadership skill growth and hands on activity practice (Mosatche et al., 2013; Slavit et al., 2016). For example, my experiences with many school activities, such as camping with my family, pet ownership, Girl Scouts, sailing camp, Girl's Technology Camp, and 4-H workshops while I was a student were all positive. This involvement helped craft me into a caring science teacher who brought many personal experiences into the classroom for students to relate to and made me more passionate about teaching these topics.

After School Learning

Several out-of-school programs have been identified as maintaining the fun factor and getting students excited about STEM. 4-H, scouting, Tech-bridge, Girls for Tech-bridge, and Access for Young Women all build on leadership and STEM skills through hands-on activities, college visitations, role models, and career explorations (Krishnamurthi et al., 2009; Mosatche et al., 2013). Research experts explain that for students the most crucial learning techniques include collaboration, real-world problem solving, hands-on application, and creativity (Cooper & Heaverlo, 2013). After school learning allows students a chance to obtain real life skills, increases knowledge and excitement about STEM topics, and increases the likelihood of a STEM career (Dierking & Falk, 2016; Krishnamurthi et al., 2009).

If students spend time in activities that make science relatable to their life and exciting, they will strengthen their school affinity with science (Cooper & Heaverlo, 2013; Dierking & Falk, 2016). Research reports that 71% of 4-H science participants say science is now one of their favorite subjects after participating in afterschool STEM club (Krishnamurthi et al., 2009). The Afterschool Alliance (2013) reports that the most effective afterschool activities include these goals: (a) increased attitude towards science, (b) increased skills in science, and (c) increased chance of science careers. Recent research on STEM after school programs found that year-long programs can enhance students' interest in STEM topics, like space and STEM careers (Wilkerson & Haden, 2014).

After school programs can provide healthy mentorship, structure, and an awareness of STEM topics that continues learning outside of the classroom.

Girl Scouts

Scientist Shirley Ann Jackson explains how to connect students using science with promoting experiences where students become excited about science and encourage them to become scientists and engineers (NPR, 2009). Girl Scout CEO Sylvia Acevedo's love of space and engineering skills launched her career as a rocket scientist at NASA's jet propulsion lab, and she later led Fortune 100 companies Apple and Dell (Acevedo, 2018). Her enthusiasm in science and engineering was sparked by participating in Girl Scout activities (Lansat & Feloni, 2018). Acevedo explains,

> I first got interested in science when I was at a Girl Scout campout and I was looking at the stars and my troop leader noticed that and she showed me constellations. So I started taking science and math electives in school and then I realized that I could be an engineer because of the confidence I had at Girl Scouts. (as cited in Lansat & Feloni, 2018, para. 6)

From scientists Jackson and Acevedo, we learn that we have to spark students' interest in STEM early and use activities like free time outdoors and Girl Scouts to ignite STEM interest. It is critical to identify what sparks a STEM educator into becoming committed to this style of teaching.

Mentors

An essential element of fostering personal growth is the role of a supporting mentor. Research identifies a mentor as someone who cultivates potential and celebrates improvements (Rath, 2008). A mentor can be a cheerleader, a sounding board, lead by example, or be the goal to emulate. Research reinforces that a supportive mentor connection can be the sole reason for a mentee having success (Haring, 1999). The mentor/mentee affinity is a part of what develops a STEM leader.

Popular in mainstream media for her neurobiologist role on *The Big Bang Theory* is actress Mayim Bialik. Bialik is a real-life Ph.D. in neuroscience who advocates for STEM through her role as a Texas Instruments and C1 Coders spokesperson. She has proposed the theory that we introduce students to STEM early and show them basic skills, so we can get them hooked on the creativity and passion of solving problems in a STEM world (Bialik, 2015; Myers & Berkowicz, 2015). Bialik shares that her role model came in the form of a passionate female biology tutor when she was 15 (as cited in Casserly, 2013). Bialik expresses her fervor specifically for females becoming involved in STEM in the following quote:

> I think every student is inspired by something different. That’s why it’s important for us as teachers—and people in a position to mentor—to be able to provide girls with as many realistic science situations as possible. To show them that not everyone starts as a scientist but you can still be interested in it later in life. So as far as my own passion, it’s nice to play a scientist on TV and that, I suppose, makes me a role model. But I also think it’s wonderful to be able to use that platform to be able to influence—hopefully positively—young girls and to show that science is cool. (as cited in Casserly, 2013, p. 1)

In her role as a scientist on *Big Bang Theory*, Bialik brings forth the familiar image of STEM in the media of science, a solitary scientist working alone in a lab or a mathematician bent over a calculator. We need to show a clear picture of what real world STEM looks like for students. Bialik emphasizes, “We must show young women from a young age, the varied and creatively driven fascinating careers available to them in science, math, and engineering" (Bialik, 2015, p. 1). Mayim Bialik continues to inspire future STEM leaders from both her role as a scientist on TV and as a coding technology ambassador, which shows her devotion to making STEM exciting and relatable to students.

Challenges With Mentors. There are difficulties with mentorship. It can be burdensome to locate a mentor of the same background, race, or gender. A deficit of minority mentors has produced a critical need for them (Nedland, 2012). This could be why individuals are not committed to STEM teaching. The lack of minority mentors adds to the difficulty of creating equal access for all. If a mentee does not have someone who has overcome similar struggles to themselves, it can be difficult to relate to them. Mentorship does not need to be a formal process as research shows that informal mentoring promotes encouragement (Gorman et al., 2010). It is important that the mentoring experience is supportive because the mentors are cultivating future educators into STEM leaders.

***Teachers*.** Effective teachers build affinities with their students and create a sense of trust and respect which generates a productive environment for students to explore science. Hanson (2009) reports that girls liked science if they connected with the teacher or if the subject was made fun. It seems serendipitous to count on a student liking a teacher in order for him/her to be committed to the topic, but the core is building positive affinities with students. Hanson (2009) further explains, "Most notably, it is strong, supportive affinities with teachers that makes the difference between . . . youth who succeed academically, even in the difficult mathematics and science courses and the ones who do not" (p. 45). Rice et al. (2013) share,

> Teachers have considerable influence on children because of their authority in the classroom. Students' perception of positive instructional approaches (i.e., teacher support and engaging instruction) is associated with better attitudes and higher self-efficacy for math and science. (p. 103)

This brings attention to the powerful role that teachers play in connecting students to science.

Conceptual Framework: Teacher Leader Model Standards

For the purpose of this research, I used the Teacher Leader Model Standards (Teacher Leadership Exploratory Consortium, 2011) as a conceptual framework for the elements of describing possible attributes of a STEM teacher leader. Teacher leaders are described as motivators with vision who encourage others to take action (Hunzicker, 2017). Teacher leaders can be described as supporting fellow teachers to embrace change and do not make the change about themselves (Klein et al., 2018). Leaders do not wait for administration to identify teaching issues along with possible solutions (Klein et al., 2018). There are multiple reasons to encourage teacher leaders in schools: specific expertise, opportunities for a promotion, or principals needing help meeting school expectations (Nickerson et al., 2018). Promoting teacher leaders to support their school can improve teacher retention rates, developing teacher capacity, and positively influence school culture and student academic learning (Catone et al., 2018). Compelling research exists in teacher leadership; however, STEM leadership is considered an under-researched field (Klein et al., 2018).

The Teacher Leader Model Standards (TLEC, 2011) were constructed through a collaboration between state education agencies, teacher leaders, principals, superintendents, and higher education institutions. The purpose of the TLMS is to guide the preparation of exemplary teachers into leadership roles. The TLMS Consortium recognized that these critical leadership roles that teachers play facilitate both student and school achievement success; thus, the TLMS can be transformative to support teacher leaders (TLEC, 2011). Teacher leaders may contain some of the attributes on the list, as it is not necessary to have them all in order to be considered a leader. For the purpose of this study, these attributes include how I characterize a STEM teacher leader. See Table 1 for the Teacher Leader Model Standards.

Table 1

Teacher Leader Model Standards

Standard	Description
I) Fostering a collaborative culture to support educator development and student learning.	● Culture building responsibilities such as modeling, learning and innovation, collaborative planning, and discussing diverse viewpoints help create a cohesive culture (Hunzicker, 2017). ● Teacher leaders will informally share professional experiences that influence their peers through building connected affinities (Klein et al., 2018). ● It is critical for teacher leaders to establish a supportive climate for collaboration (Nickerson et al., 2018) in order to foster affinities so that teachers feel safe contributing, as everyone will gain when diverse ideas are shared (Wenner, 2017).

Table 1

Cont.

Standard	Description
II) Accessing and using research to improve educator development and student learning.	● Teacher leaders can foster partnerships with universities, which promotes external support and confidence in teaching in new areas (Klein et al., 2018). ● Teacher leaders must also interpret the new ideas and connect them to the curriculum map, so that staff have a better understanding of how they work (Wenner, 2017). ● University alliances can provide coursework, informal interactions, and professional development to grow teachers (Klein et al., 2018).
III) Promoting professional learning for continuous improvement.	● Teacher leaders cultivate professional development and create a climate where staff is receptive to feedback (Hunzicker, 2017). ● Supporting peer teachers through affinities helps craft a climate where staff want to work cohesively with the shared goal of student achievement (Nickerson et al., 2018). ● "Science Teacher Leaders also help teachers by guiding professional development at their schools via modeling lessons, serving as a resource for ideas and content, and determining what topics were needed by the teachers," (Wenner, 2017, p. 120).
IV) Facilitation improvements in instruction and student learning.	● Teacher leaders develop affinities, so they can mentor and facilitate coaching to support teachers (Hunzicker, 2017). ● To foster improvements teacher leaders will use observation data to create a connection to discuss reflections and equity concerns in order to promote growth (Teacher Leadership Exploratory Consortium, 2011). ● Defining which teachers need extra support and sharing successful methods creates opportunities to facilitate best practices and is necessary for improvement (Cosenza, 2015).

Table 1

Cont.

Standard	Description
V) Promoting the use of assessments and data for school and district improvement.	● Teacher leaders understand that using school data to make decisions will positively improve student learning (Wenner, 2017). ● It can be very useful for teacher leaders to design and score assessments and help teachers interpret the data (Teacher Leadership Exploratory Consortium, 2011). ● Data talks, reviewing expectations, comparing lessons, and assessment outcomes all connect with the objective to improve instruction (Wenner, 2017).
VI) Improving outreach and collaboration with families and community.	● The research evidence supports that teacher leaders utilize community partnerships and family connections to share new ideas and resources to create equitable student experiences (Catone et al., 2018). ● Outreach may include after school programs, science fairs, field trips, assisting in the application process for magnet programs, or family nights (Wenner, 2017). ● Being culturally responsible will improve schools' outreach and collaboration (Teacher Leadership Exploratory Consortium, 2011) and allow communication of the school vision with the community and families (Wenner, 2017).
VII) Advocating for student learning and the profession- teacher leaders are necessary for school growth.	● Teacher leaders implement policy that influences support of the district and state objectives in order to advocate for student needs (Klein et al., 2018). ● Teacher leaders have a responsibility to address staff concerns and engage in advocacy for policy reform that will bring improvement (Catone et al., 2018). ● A STEM example is focusing on teacher leaders supporting NGSS and modeling the new scientific engineering lens for teachers (Klein et al., 2018; Wenner, 2017). ● "Teachers are best positioned to both implement policy and lend their pedagogical and content knowledge, expertise, and familiarity with students and families to understand how policy plays out on the ground in classrooms, schools, and communities" (Catone et al., 2018, p. 9).

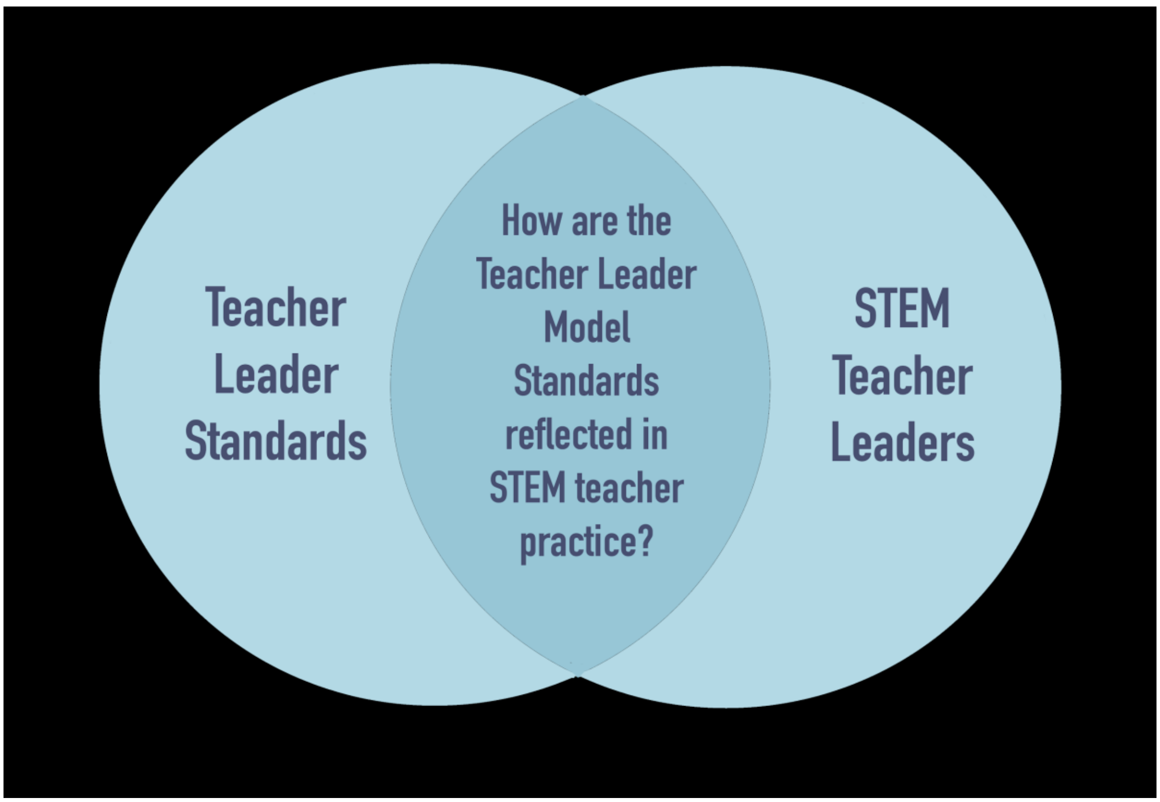
The TLSM characteristics are important because they describe the critical roles that construct a teacher leader. Collaboration provides the supportive climate for teachers to share and plan towards a common goal; while research minded teachers are open to updated concepts and help share the new ideas. Teachers connected to professional development are lifelong learners who are motivated to guide peers, model best practices, and encourage feedback. A focus on instructional improvements fosters a common bond to focus on best practices. Additionally, teacher use of data and assessments focuses the lens on examining student outcomes and adjusting practices for students' growth. Family and community teacher involvement connects a shared vision with all the stakeholders in order to collaborate towards student success, while advocating for student learning reflects on a responsibility to support changes in policy for students' best interest. Each TLMS characteristic's goal is to engage students in learning, as this is the common goal of a teacher leader. This is all important for STEM teacher leadership because each of these critical components work towards establishing, connecting, and fostering STEM growth.

Through using the TLMS as a conceptual framework there is a focus placed on identifying these characteristics in the STEM teacher leader participants. Looking at their effectiveness and realistic practices in STEM through the lens of TLMS creates an authentic view of the pedagogies, practices, and stories of participants. The use of the TLMS as a framework brings order and highlights this STEM teacher leader research.

The review of the literature resulted in discovering the Teacher Leader Model Standards (Teacher Leadership Exploratory Consortium, 2011), which identified the characteristics of an effective teacher leader. Discovering which experiences and pathways influence a STEM teacher leader and viewing the pedagogical practices used through the lens of the Teacher Leader Model Standards will result in a rich description of a STEM teacher leader.

Figure 2

STEM Teacher Leader Model. Researching the Space Where the TLMS Meet and They are reflected in STEM Teacher Practice.



Conclusion

This literature review highlights a void in existing literature. Notably missing are the specifics on STEM leadership. Specifically, STEM leadership is critically needed, so that educators can transform lives with implementation of STEM innovation in classrooms. STEM leadership needs to be fully developed so that we can guarantee that all students are receiving the support they need to achieve STEM success. Urgent needs include providing deliberate support to minority students in STEM and including well-designed actions.

Connecting the pathways of STEM teacher leaders may allow an understanding of how their interest and commitment to STEM subjects began. Research indicates that after school activities, such as 4-H, allow students opportunities to solve realistic concerns with hands-on instruction. Other afterschool activities like Girl Scouts foster an empowerment for females to enjoy experiences in scientific fields (i.e., astronomy, technology, or engineering). Mentors are identified as having a critical role in supporting STEM leader growth. However, a major challenge of STEM mentors is locating one who is accessible and who reflects the same interest and has a similar background. Research identifies that a supportive teacher is the deciding factor in students who excel in their subject matter. Inspiring teachers to become committed, engaging STEM teacher leaders is crucial in fostering student success. Distinguishing and analyzing an in-depth understanding of the Teacher Leader Model Standards will create a comprehensive view of committed STEM teacher leaders.

This chapter indicates that STEM teacher leader research is inadequate in the areas of teacher identity, integration, professional development, and curriculum development. STEM best pedagogy practices were identified as: creativity collaboration, inquiry, real world applications, and reflections. Each of these pedagogies inspire effective, investigative teaching where students have ownership of their learning and are willing to take risks. Teaching with these best pedagogical practices are not without their challenges, including limited professional development, weak college preparation, curriculum difficulties, and lack of confidence. This research also explores STEM leadership through identifying a STEM teacher leader as a risk taker who is empowered to inspire students with STEM. Understanding STEM teacher leaders' pathways, which include their afterschool learning experiences, mentors, and personal teacher affinities, helps create an understanding about what pathways supported the teacher. Finally, the Conceptual Framework using the TLMS as a lens to view participants characteristics is pivotal. The use of TLMS brings focus into how to view participants descriptions of STEM classroom usage. Chapter III discusses the mechanics of how this research was conducted.

CHAPTER III

METHODOLOGY

In this qualitative research study, I examined experiences and influences that spark passion for STEM teacher leadership and used the Teacher Leader Model Standards (Teacher Leadership Exploratory Consortium, 2011) as an analytical framework for exploring the experiences and practices of STEM teacher leadership. In this chapter, I articulate my research design, methodology, data points, and ethical considerations.

Pilot Study

As part of my coursework, I completed an Institutional Review Board (IRB) approved mixed methods study, *What Influences a Female Student to Select STEM Courses and Experiences?* The data I collected consisted of survey results and a focus group interview. The participants were female elementary, middle, and high school students. From the study, themes emerged about what influenced the participants' STEM pathway, including school/family/peer influencers, outside school activities, and media. This pilot made me reflect on how teachers were strong influencers of students, so questions arose about how teachers are influenced. Many of the participants described a person or activity that lit the spark of STEM interest, which motivated me to study what inspires STEM teacher leaders. After completing this pilot study, I realized I had more questions about STEM and schools—most specifically, the details of a STEM teacher leader.

Research Questions

Research questions are crafted so that the participants can share their STEM knowledge and experiences (Creswell, 2015). Qualitative research questions allow me to research what I am most curious about and craft this interest into a STEM topic that can be researched (Merriam & Tisdell, 2016). Thus, this qualitative research study sought to craft a better understanding of this over-arching research question:

What are the experiences and practices of STEM Teacher Leaders?

Two focus questions further define the study:

- How are the practices of STEM teacher leaders reflected in the Teacher Leader Model Standards?
- How do STEM teacher leaders instructionally enact the pedagogical practices of creativity, collaboration, inquiry through real world problem-solving, and reflection in classrooms and schools?

Specific Methodology

Qualitative research seeks to make sense of the world and people's experiences through words (Merriam & Tisdell, 2016). Using qualitative research allows the researcher to be personally in the center of an investigation through his/her interactions and interpretations (Lichtman, 2013). Learning how people behave and make meaning of this world is the nexus of an interpretive qualitative approach (Merriam, 2002). I utilized qualitative research methods to investigate *how* are the practices of STEM teacher leaders reflected in the Teacher Leader Model Standards and *how* do STEM teacher leaders instructionally enact the pedagogical practices of STEM?

Qualitative data can include documents (emails, articles), archival records (test scores), interviews (open-ended), and direct observations (field notes) (Creswell, 2015; Lipton & Wellman, 2012; Merriam & Tisdell, 2016; Tellis, 1997; Yin, 2003). For the purpose of this qualitative study, I collected data from interviews (Creswell, 2015; Lipton & Wellman, 2012). Using this rich dataset revealed a deep, complex picture from the descriptions of the participants, which translated into broad themes through analysis. I am committed to learning how to best support STEM teacher leaders' pathways and practices, so they can support and advance all students.

Significance of the Study

Currently the state of North Carolina does not have a STEM teacher leader system in place to equip STEM teachers with support. We must work to understand how STEM leaders teach in order to better equip other educators. I want to understand participants' leadership efforts through STEM. Understanding how STEM pedagogies are used, and identifying how teacher leaders influence student achievement, will help prepare and inspire future STEM teachers. We can also learn how to provide STEM teacher leader support to continue fostering new STEM teacher development.

Design of the Study

This qualitative research study on a selected group of committed elementary STEM teacher leaders involved participants sharing the how and the why of their STEM journey. The intention is that we uncover the pathways and teacher leader practices of committed STEM teacher leaders.

Setting

The selected setting for this study is a rural school district in the Southeastern United States. This district includes 24 schools, including five high schools, four middle schools, 12 elementary schools, and a college partnership STEM school. I did not select any participants whom I supervise as a part of the study. This eliminates participants feeling that they must respond in a certain way in order to please me as their supervisor. It also allows participants to respond honestly, because they do not fear retribution from their current supervisor about their responses.

Participants

I studied committed STEM teacher leaders from elementary schools. Participants ranged from beginning teachers through veteran staff members and the participants varied in age and gender. The participants were given pseudonyms for this research. I sent a request for recommendations to current district leaders who would be in a position to identify committed STEM teacher leaders. Through my pilot research I have also identified several STEM teacher leaders. Initially, six participants were recruited and agreed to participate. The initial plan was to include these six participants in a focus group interview as the conclusion of the study. However, COVID-19 halted face-to-face interview opportunities. Therefore, I returned to the district level staff for additional recommendations. From these nominations, I recruited four more participants, who completed the interview process remotely. Interviews were completed over FaceTime or on the phone, due to Internet limitations. I did try to strategically recruit racially diverse participants, but I was unsuccessful. For this study, ten participants were recruited and six participated in face to face interviews and four completed interviews remotely.

Table 2

Participant Demographics

Team Member	**Name-Age Range**	**Demographic data**
Third-grade Teacher	Marta – 30s	White female
Fifth-grade Teacher	Adeline – 40s	White female
Fifth-grade Teacher	Chad – 30s	White male
Second-grade Teacher	Winnie – 40s	White female
Fifth-grade Teacher	Minerva – 50s	White female
Fifth-grade Teacher	Leigh-Dell – 30s	White female
Fifth-grade Teacher	Fern – 30s	White female
Second-grade Teacher	Rory – 50s	White female
Fifth-grade Teacher	Barbara – 30s	White female
Fifth-grade Teacher	Shelby – 20s	White female

Participants were given choices for meeting spaces for the interview and all the face to face interviews selected their classrooms. The interviews that were conducted over Face Time were completed by the participants in their quarantine location. Participants selected their interview location in order to be most comfortable.

Participant Mini Biographies

Marta

Marta worked hard to get her education starting with a GED, then community college, followed by a 4-year degree. She also had to work to put herself through school with a small child. She has shown she is a fighter as she overcame many difficulties to become a teacher. She has just finished her last year in the beginning teacher program and is starting to stretch into new programs and materials that show her interest in STEM. Her son attended an afterschool STEM club that launched her interest and a professional relationship with the STEM club instructor. Marta is a STEM teacher leader, because she has planned for monthly STEM lessons that are integrated into her curriculum. She also assists with her school STEM club.

Adeline

Adeline is a determined individual, as marked by her dropping out of high school, completing a GED, then reaching her bachelors in elementary education. She has overcome many family struggles to become a teacher leader. She is candid as she shares with her students mistakes she made and encourages them to think about their choices and be reflective. Adeline credits compassionate teachers who built personal connections with her and motivated her to become a teacher. This road of choices built the person who she is today, aware that these experiences made her stronger, so she was prepared to help students. Adeline has recently been accepted into a Science Masters Education program as she works to continue to grow her STEM passions. Adeline is a STEM teacher leader, because she teaches with an emphasis on the use of inquiry and phenomena and runs the school's STEM club. She also serves as a schoolwide digital learning coach.

Chad

Chad was on a path to journalism when a high school cadet program gave him new insight into the meaning of teaching students something new, the retention process, and the student eagerness for more information. This spark continued with supportive college professors who took a special interest in providing support through being available and pep talks. Chad was inspired to meet class challenges through the use of new STEM pedagogies that implement a shift in instructional approach. Chad was drawn to science because it allowed him to learn something in class then go out and see it in action in the real world. This drew him to becoming willing to learn about STEM. Chad harnesses the Dojo platform to send parents images for the students to engage their parents in conversations about things that they learned in class that day. Chad is a STEM teacher leader, because he teaches with inquiry, collaboration, and creativity in his integrated STEM lessons. He has also had many unique experiences with supporting professional development related to STEM.

Winnie

Winnie played school as a child, but she became focused on the career path when she became a parent to a kindergarten student with an incredible teacher. This experience made her want to become a teacher. As the first in her family to earn a four-year degree, Winnie is modest about her achievements. When Winnie taught in a team-teaching partnership, she wanted science because she had enjoyed hands on science activities as a child. As a high school student, she had hated science, so this became a challenge to teach science in a way that was engaging to students. Winnie seeks out STEM professional development in order to support student growth through personalized learning. Winnie excels in parent communication through the Dojo platform and connects parents with student classroom learning. Winnie is a STEM teacher leader, as she serves as a schoolwide digital learning coach and inspires many teachers with her STEM and digital literacy skills.

Minerva

Minerva entered education in a non-traditional way by becoming a social worker and supporting students. She earned a Master's in education and received her a position teaching 5th grade. Her non-traditional role brings her psychology lens and approach to how she creates connections with students and interest in all things science. Minerva describes herself as a rich, engaging childhood with a professor for a father who spent time engaging her in the mysteries science had to offer. This interest in science turned into robust conversations as an adult about the why behind science phenomena. While living in Australia as a child, Minerva not only had the experience to assist her father in his Great Barrier Reef research, she had a culturally sensitive teacher who inspired her to teach. Minerva is a STEM teacher leader as she is a huge advocate for science and technology education and consistently teaches collaborative lessons.

Leigh-Dell

Leigh-Dell was inspired by a family of educators. Until her father's recent retirement, both her parents taught in the same rural school system, along with her brother. Education was beyond a calling; it was part of her family. Her interest in teaching began in kindergarten and extended to earning a master's in curriculum. Leigh-Dell feels very drawn to the inquiry curriculum because she does not have to tell students exactly what to do or what the end result should be. Student choice and voice is alive in her class and this motivates her to learn more about inquiry-based science education. Leigh-Dell is a STEM teacher leader as she consistently uses hands-on and collaborative teaching methods, along with STEM curriculum in her classroom.

Fern

Fern was inspired through her high school teacher cadet program. She had the experience of returning to her personal elementary school and meeting student needs through this program and that launched her into an undergraduate and master's degree in education. She worked as a community college instructor before returning to elementary school. It is ironic that Fern became a teacher—as a self-proclaimed hater of school she acknowledges the support of past teachers that inspired her to love teaching, even math, which was once one of most disliked subjects. Fern explains that her love of organized sports kept her motivated in school so she could participate in them. It is no surprise that her coach-like attitude and focus connect with her students to become interested in topics, even math. Her focus on data driven instruction and creating opportunities for students to own their data are a hallmark of her classes. Fern is a STEM teacher leader as she leads with data-based instruction, inquiry, collaboration, and creativity in her STEM lessons. She also supports other teachers within her school building with STEM needs.

Rory

Rory became a teacher and earned a Masters in technology education curriculum. She found her calling as a primary inclusion teacher and reached out for the most high-needs students. Her thinking outside the box methods combined with a sunny outlook made her an excellent fit. Rory's class tends to be louder than most, messier than most, and a bit unconventional. A daily occurrence is the love of learning that erupts in this class or the engaged students in STEM creation tasks. Rory has shown that removing herself from center stage allows these students a chance to do and explore and that is exactly how she likes it. Rory also excels in making personal connections with students and families which heightens the support and engagement in her class. Rory is a STEM teacher with her hands-on experience approach to STEM lessons and she serves as a schoolwide personalized learning coach.

Barbara

Barbara received a 4-year degree in education and has taught fifth grade her entire career. Her initial goal was to become a lawyer. That changed after a high school cadet internship in a kindergarten class. Barbara has a sister who is special needs, but a class of only special needs students appeared overwhelming to this high school student. Through her cadet program she learned about special needs inclusion processes and that inspired her to become a teacher where she could help special needs students, like her sister. It would just look different as inclusion. Barbara also described hating math and science as a student, so as a teacher so she vowed to teach in a way that engaged students into these subjects. Barbara is a STEM teacher leader as she adds STEM elements into her lessons and serves as a schoolwide digital learning coach.

Shelby

Shelby is a beginning teacher who has been recognized for local and state achievements. She graduated from an undergraduate program with a STEM education focus. She always knew she was going to be a teacher and practiced on her stuffed animals as a child. Shelby works hard to build personal affinities with her students. It is clear there is an order to everything that she does with a focus on achieving student growth. Shelby is knowledgeable, prepared, and ready to implement ideas she was instructed on as an undergraduate. Shelby is a STEM teacher leader with her STEM education background; she is poised to add STEM lessons into her classroom.

Data Collection Methods

Data collection consisted of individual interviews. My plan was to "expand and extend beyond a purely descriptive account with an analysis that proceeds in some careful, systematic way to identify key factors and affinities among them" (Wolcott, 1994, p. 11). The University of North Carolina at Greensboro (UNCG) Institutional Review Board (IRB) and the public school system research agreement were procured. My IRB approval, consent form, and approved interview protocol are in Appendixes A, B, and C, respectively. All necessary documents were collected and copies are available within the IRB proposal. I reiterated the study purpose and shared consent forms with all participants. For security purposes, all of the documents are stored in UNC Greensboro's digital cloud-based secure platform, Box.

I met with the first six participants at their schools. For each participant, I would remind them of the research plan, thank them for their involvement, and explain about audio recording the interview. The data collection consisted of in-depth, open ended interviews with STEM teacher leaders for 60 to 90 minutes. The interviews were audio recorded and transcribed. In order to elicit a conversation with the participant the interviews were semi-structured. Each interview lasted approximately 90 minutes. For each interview, I used the IRB approved questions outline to create consistency between the interviews.

When COVID-19 pandemic created the need for the stay at home orders I resubmitted my IRB to reflect these changes and completed three of these interviews over Facetime and one on the phone. I then used my laptop to audio record each interview. The phone interviews tended to last longer, about 2 hours each. It is worth noting for one interview we had some internet issues and the participant followed up with clarification. The interviews sought to provide a conduit for promoting a flexible and adaptable method of collecting responses from participants and encouraged details to create the STEM teacher leadership story (Merriam & Tisdell, 2016).

I made field notes during the interviews to make sure I noted body language, facial expressions, and other visuals. All the completed interviews were transcribed. The transcriptions were emailed to each participant for a member check. Several participants made corrections and clarified stories in their interviews. None of the member check reviews changed the meaning of the data collected This gave each participant the opportunity to read over their individual interview to check for validation and accuracy.

One participant completely removed all of the colloquial speech in her member check. This member check was another strategy in triangulation of the data.

Data Analysis Strategies

Through the analysis process, the researcher looks for patterns that repeat in the data to build a meaningful story (Merriam & Tisdell, 2016). Qualitative data can be analyzed by "descriptive accounts, themes, or categories . . . through the use of concrete bits of data and abstract concepts, between inductive and deductive reasoning" (Merriam & Tisdell, 2016). For the coding of the data (126 codes total), I went through transcripts line by line and noted key phrases to the side margins. There were 126 of these codes. Next, I charted the codes into 36 categories, by reviewing the transcript notations and making notes. I placed these categories onto notecards and sorted them into four themes. The four themes emerged as the key takeaway points the participants communicated. I then copied each participant response from the transcriptions into a spreadsheet by category. This helped me view the message as a collective voice. Many of the Teacher Leadership Model Standards (TLMS) did show up as codes and categories in the data analysis. Before I began my data analysis, I had initially assumed that the TLMS would be primary codes, but it is impossible to anticipate what participants are going to share.

The interviews were audio recorded and transcribed. During the interviews, I made field notes of reactions, mannerisms, and emotions. Field notes and interview transcripts were coded using priori coding and codes that are derived from the text. I coded as I collected data in order to classify and not forget important details (Merriam & Tisdell, 2016).

Efforts were made to connect the priori codes to the conceptual framework plan. When I coded the data, I used the transcription data to create the 126 codes. These codes were charted into 36 categories, which I wrote on notecards. By placing the categories on notecards, I could practice putting them into different groups until I determined the best fit. These 36 categories were sorted into 4 themes. I then copied participants' transcriptions about each category into a spreadsheet thematically. The spreadsheet was color-coded to identify each participant within the collective voice. Through the use of the spreadsheet it was clear to see the data simultaneously as individual participant messages and as a collective voice. From the data analysis I was able to report the collective participants thematically through the four themes that emerged: STEM teacher leaders exhibit an affinity to STEM related subjects, experiences, or teachers, family, or mentors., STEM teacher leaders use integrated STEM pedagogies, Descriptions of a STEM teacher leader, and STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches.

Triangulation of the data means that more than one method was used to collect data to ensure validity (Merriam & Tisdell, 2016). In this study, the triangulation of the data analysis occurred by collecting data from multiple interviews, member checks, and coding counts. Part of my triangulation then counted how often a category showed up in the transcripts. I used the “Find and Select” function to select the phrase and words related to a category. I then would read the highlighted section and would count the frequency of topics. This strengthened my research because I could pinpoint the number of times a topic was discussed. Triangulation showed the data results to me meaningful, by cross checking interviews and sources (Merriam & Tisdell, 2016). Lipton and Wellman (2012) proclaim, “Triangulation is an effective method for increasing credibility and dependability when in data exploration” (p. 58).

To preserve the integrity of this research, participants and schools are identified through the use of pseudonyms. Multiple sources helped me craft a complete vision of STEM teacher leaders. There is a clear data trail with field notes, transcriptions, and analysis stored digitally in a passcode protected platform.

Trustworthiness/Ethical Considerations

Qualitative researchers should identify their biases, so they are not derailed by them during the research (Merriam & Tisdell, 2016). As a former teacher and current administrator, I am focused on using STEM for all students to help them achieve success. I personally disliked math as a student. Additionally, I was interested in a science career choice growing up and was discouraged. Therefore, I wish I had been taught through the STEM process. It makes me particularly driven to understand the influences of STEM education. I am biased in that I think educators should be teaching STEM through best practices pedagogies. I did expect to see the influence of mentors and positive school experiences that influenced STEM leaders. However, I did not show disappointment if these areas did not show in the data. An ethical checklist for qualitative researchers identifies areas of possible compromise to keep researchers focused. The list includes data collection boundaries, data access, and confidentiality (Patton, 2015). I continue to be eager to learn how we can overcome barriers that keep educators from using STEM. I assumed that fellow educators would be familiar with the STEM themes and terms. In order to negate any possible confusion, I did define the words aloud before my interviews to participants.

As a researcher, I used a reflection journaling tool after the interviews. This helped me collect my initial responses, as well as identify any possible bias that I may have as the researcher. I did not want my bias or assumptions as the researcher to sway the participants' responses. I practiced a self-check with wording for interview questions and responses. I believed that if participants felt that I judged their answers, they would feel less likely to want to participate or be honest.

I am aware that I work as an administrator, yet I completed this study as the role of student researcher. I did not want to abuse my power or influence. I worked to create common ground by explaining that I am a student. I was cognizant of the use of leading questions and selected the time and location for interviews that are not persuasive, like the participant's office, media center, or a centrally located public place.

Because I am a passionate STEM leadership doctoral student, I was well positioned to conduct this research. I was careful to dress business casual, without being too formal, as I want to put my participants at ease without being too professional. I attempted to connect as a fellow educator who cares about students and STEM and would like to give STEM teacher leaders a voice. I want to be able to share the STEM leadership pathway story in the hopes of helping other future STEM teacher leaders.

Limitations

Limitations exist when researchers purposely or unknowingly place loopholes or omit information within their research. Some limits may occur with qualitative research including a small sample size, difficulty in procuring participants, or inability to generalize findings (Creswell, 2015; Lichtman, 2013). Researchers should be transparent in acknowledging their limitations for the research to be clear.

A limitation of my research was the noticeably missing STEM teachers of color and male participants. I purposely recruited multiple accomplished STEM teachers of color and male teachers who all declined to participate. However, in looking at the recent research Wong (2020) states that there is a drastic gender imbalance in elementary schools with 9/10 teachers being female and Moss (2016) remarks that even though 50% of students are children of color 80% of their elementary teachers are White. With this data, it is not surprising that the limitations include the absence of teachers of color and male teachers. Chapter V continues a discussion of this limitation.

Misunderstandings

Some experts express that qualitative research without examples limits the level of respect for them (Lichtman, 2013). Although STEM teacher leadership continues to be a popular phrase in education, there is limited research from which to draw comparisons. To overcome validity concerns, researchers must be strategic with thorough documentation, data collection, and a rigorous proposal plan to glean the most efficient participant support. In order to provide a documented trail of triangulation the data collection, coding, and analysis was completed with the utmost precision and care.

Benefits and Risks

This STEM leadership qualitative research is a current topic. Considering the gaps in the published literature and the popularity of STEM as an ongoing and a constant in education and practices of the 21st century made this a very compelling and high interest topic. Benefits included understanding the pathways of STEM teacher leaders and reflecting on the leadership role influencing students. Participants articulated challenges, successes, and future plans for STEM. The information gathered created recommendations for STEM programs, which is a potential benefit to education. Wolcott (1994) explained that the analysis completed with research is “a diagnosis on which a prescription action should be made, a launchpad for further study, or a case examined and closed” (p. 29). This analysis is used as a launchpad to identify indicators, to create powerful STEM programs, and to provide recommendations for implementation within the school system.

Risks included trust issues, as the participants may perceive me as an administrator and want to please by giving what they perceive to be the correct, desired outcome. Participants could have feared sharing authentic challenges, as so not to seem incompetent at their career. Wolcott (1994) states, “Research is a means of organizing our thoughts to reach understanding, not an end in itself” (p. 37). It is my belief that the benefits of the research identifying indicators and learning how to strengthen them outweigh the possible risk of trust and fear. The benefits of this study include, school leaders and teachers reflecting on STEM pathways and recognizing them as worthy of research focus. It could encourage participants to consider the critical importance of teaching students these skills. As a school leader, I would like to facilitate in-services, support school leaders, and encourage STEM use in schools.

Risks could be for any teachers who may feel they should answer a specific way in order to please the researcher or their principal. They could have feared repercussions in admitting their beliefs about STEM and what hinders them from teaching with STEM. In order to protect the participants, the transcripts, coding spreadsheets, and document policies that identify participants by name are kept in password-protected software. Paper copies with identifying information are kept in a locked filing cabinet in my home. Participants are only identified in the study by pseudonym. I believe that these layers of protection helped participants feel that the risk was minimal. STEM could be the answer the United States is desperately seeking to connect more students to future career paths for jobs that have yet to be invented. More research is needed to better understand what pathways influence a STEM teacher leader and what their practices are (Guzey, Moore, & Harwell, 2016; Slavit et al., 2016).

Summary and Forecast

In Chapter III the research questions for this study were explained:

This qualitative research study sought to craft a better understanding of this over-arching research question:

What are the experiences and practices of STEM Teacher Leaders?

Two focus questions further define the study:

- How are the practices of STEM teacher leaders reflected in the Teacher Leader Model Standards?

- How do STEM teacher leaders instructionally enact the pedagogical practices of creativity, collaboration, inquiry through real world problem-solving, and reflection in classrooms and schools?

These research questions drove this qualitative study. A biography of each participant created interest for the reader in their personal story. Data collection details were shared including the IRB process, semi-structured interview plan, and audio recorded interviews, followed by member checks. The data analysis strategies included coding, categories, then themes to organize the data. The trustworthiness of the study expressed by the use of triangulation, personal bias, and the use of pseudonyms. Reporting the data via the use of themes was explained. Limitations to the study, including misunderstandings and risks were noted. Chapter III explained the methodology mechanics of how the study was conducted. Next, Chapter IV reveals the rich stories the participants shared in this qualitative study. The participants' responses were collected and are shared thematically.

CHAPTER IV

FINDINGS

This chapter presents the stories of teacher leader participants through the four themes that emerged from the data. Coding the interview data collected from ten teacher leader participants, followed by the analysis of each code, led to identifying four themes drawn from the collective voices of participants. Overwhelmingly, these committed teacher leaders described STEM as an impactful way to teach. Table 3 presents a summary of the themes.

Table 3

STEM Leadership Themes

Theme	Description
1. STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning.	Participants' experiences regarding how they became connected with STEM, the importance of developing an affinity with students, and what their affinity was with STEM
2. STEM teacher leaders use integrated STEM pedagogies.	Classroom experiences of teacher leaders as they teach STEM through inquiry, creativity, hands-on experiences, collaboration, real-world interest, and integration

Table 3

Cont.

Theme	Description
3. STEM teachers function as school leaders by modeling innovation through STEM.	How STEM teacher leaders function within their schools through their roles leading professional development and advocating for students, and how they used data
4. STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches.	Among the challenges facing STEM teachers are time, resources, administrative support, and lack of professional development

Theme 1: STEM Teacher Leaders Exhibit an Affinity to STEM-Related Subjects, Experiences, or Important Figures in Their Lives Who Exemplified STEM Teaching and Learning

An affinity is a kinship of spirit or natural connection. Participants in this study revealed having an effortless connection to STEM topics, thus creating engagement with the subject matter. Affinities can entail connections with people, experiences, or, in the case of this study, the STEM subject. Supporting this theme were detailed descriptions of the affinity teachers develop with their students; the teachers' deep alliance with STEM topics led them to want to share this excitement with their students. This section comprises explorations of the subthemes of spark, students, and STEM connections.

Table 4

Theme 1: STEM Teacher Leaders Exhibit an Affinity to STEM-Related Subjects, Experiences, or Important Figures in Their Lives Who Exemplified STEM Teaching and Learning

Subtheme	Description
1. Spark	Participants’ experiences regarding how they became connected with STEM
2. Student Affinity	Participants' experiences creating connections with students with a shared affinity for STEM subjects
3. Affinity for STEM	How participants develop an affinity for STEM subjects and become committed to teaching them. This includes the integration, use of authentic STEM pedagogies, and creativity in their lessons.

Spark

Spark describes the affinity participants have for STEM. Several of the teacher leaders described early childhood experiences that led them to STEM and teaching. Winnie described a fourth-grade teacher with a magnet exploration station who piqued her interest in science. Minerva’s father worked as a university science professor, engaging in exciting science experiences with his daughter, including research at the Great Barrier Reef and developing photographs in a darkroom. Participation in enriching, science-centered activities created a strong background knowledge for participants to bring into their classrooms.

The teacher leaders shared what had inspired their interest in STEM. Some participants related stories of having STEM experiences as teachers. Marta described visiting a fellow teacher’s STEM club as encouraging her to engage in activities. She borrowed a University of North Carolina at Greensboro (UNCG) science oil spill kit and attended a UNCG STEM workshop. Fern's administrator sent her to a seminar entitled "Worksheets Don't Grow Dendrites," which provided her introduction to teaching with STEM principles. Upon Fern's return, she began to research STEM and implement the engineering into her classroom.

Winnie had hesitated to teach at a grade level where schools departmentalized the subjects. As a new teacher, she received an assignment to the subject "everyone hated": science. Despite not enjoying science since high school, she embraced the opportunity to teach science in a way that was better than how she had learned.

When Chad began college, an education professor asked the students why they were there. Chad responded, "I am here because I want to teach. I have no idea how I'm supposed to be an effective teacher if I was not an effective student when I was growing up. Can you help me?" Although the students laughed at him, the professor asked him to stay after class, vowing to teach him what he wanted to learn. Chad had an affinity with this college professor who supported his journey, making teaching real for the students. Participants felt inspired to help struggling students by teaching differently than they were taught. Specifically, the teacher leader participants conveyed an evident pursuit to connect students with STEM.

Student Affinities

Participants described creating meaningful connections with students and their families. Marta shared an example of a student's speech in which the student announced that his teacher made him feel safe. With tears in her eyes, Marta continued,

> They asked him if anyone ever made fun of him for stuttering, and he said they did, but “my teacher told them that wasn’t okay, and she likes me.” His mom was like, “Thank you for making him feel so secure and safe.”

Knowing that her students felt safe in her class reassured Marta that she had created a positive learning environment.

Participants explained that building an affinity with families created a shared trust, making teaching easier. Many excellent teachers outside of STEM create positive relationships with their students. However, STEM teacher leaders will use the hands-on, collaborative nature of STEM to bond with their students through the subjects. Completing STEM projects and lessons creates a unique bond; as these hands-on, high-interest STEM labs deepen the teacher-student alliance.

Most effective teachers make efforts to connect with families. Multiple participants cited interactive school social media accounts, like Dojo, as a way of keeping in contact with families. However, they agreed that nothing could replace face-to-face connections. Rory described a recent parent meeting in which they had an open dialogue about the student’s needs. The parent admitted to having a bad personal experience in school, which left her hesitant to participate. After the meeting, the parent committed to working with the teacher. Rory’s experience is just one example of the efforts STEM teacher leader participants are making to connect students’ families with the school.

Participants spoke about bonding with their students. Chad described using the moments between classes to ask about students’ interests. Many participants understood that taking time to connect with students leads to building affinities, making them more likely to feel safe and participate in class.

Rory is honest and vulnerable with her students. She explained how she conveyed to students that they have choices:

> Those are the reasons I became a teacher because if there was a bad choice to be made, I made it. . . . I tell them just enough . . . that we can have a relationship, that there's a connection. They know I'm real. I've experienced what they're experiencing. . . . I had an alcoholic dad. I had a mom who was a pushover. I love them both dearly, and everything ended up okay.

Rory's vulnerability allows students to trust her and create a bond, knowing they can go to her for help and advice. Several participants realized they had to meet students' personal needs before children would be in the mind frame to learn. Minerva shared the importance of being approachable to students:

> The kids have so many more personal problems and family problems now than they did before that it's almost overwhelming, and I feel like education for them takes a back seat to just daily survival. . . . I think teachers have to realize that the relationships that we have with all these little people—We're almost that only person anymore who is going to get them resources, get them help, identify a problem. Forget the teaching, forget the science, forget the reading, math, and all that. They've got to be able to survive first, and I think that is heartbreaking at this point.

Teaching encompasses nurturing the whole child, as Minerva expressed. It can be an emotionally charged process as educators balance helping students and involvement.

Fern described how her school pairs students with accountability partners based on their needs. The students have weekly designated time to meet with an adult, discussing the week and setting goals. Fern identified the process as being mutually beneficial. She said, "I've found out a lot about my kids that I would have never known if I didn't give them a solid platform to share with me."

Barbara described creating open time at the beginning of the day, where she works from a whiteboard table to be available to students. She was initially surprised that students adopted the choice of “time with the teacher” as a morning selection. The students sat with her: some silently, some to talk, some to ask academic questions. Barbara’s students were motivated to seek her out because she understood the importance of students’ choices and provided space for the student-mentor role to develop. Many participants shared a core belief in being approachable and creating connections to help students feel safe at school and open to learning.

Effective teachers engage in many of these practices to develop strong student and family connections. The difference with STEM teachers is the perception that these connections are nonnegotiable. Each of the teacher leaders shared how they supported these growing affinities every day, recognizing the importance of building and maintaining these connections. STEM teacher leaders engage in affinity-building opportunities due to the collaborative approach to their lessons. Promoting teamwork and hands-on lessons allows more face time with the teacher, encouraging students’ sharing and engagement with the subject and their peers. Student collaboration is limited in a normal classroom, where students are in rows and working independently.

Affinity With STEM

Participants’ affinities with STEM emerged through its definition and classroom use. In identifying the classroom characteristics unique to STEM, the participants discussed integration, real-world connections, and creativity. These details facilitate an analysis of the components essential to the participants’ affinity for STEM.

Integration

STEM is not a standalone subject; rather, integration is needed to create a rich, complex space to explore challenges. Shelby explained that STEM is a “student-centered, collaborative problem-solving [approach] that is definitely cross-curricular.” During the engineering design process, Shelby felt it was important that students write about their projects and include questions and plans. She identified the integration aspect of STEM as connecting all the writing students completed for STEM assignments.

Marta described STEM as engaged students’ problem-solving with integrated subjects. For example, in science and math, students completed standards-based hurricane experiments through research, discussion, and exploration. Barbara explained that STEM is “a way that combines all the things together to make sure you hit all those different parts [subjects] to get all your kids to understand something.” STEM teachers are in a unique position to integrate multiple subjects into their lessons. This balancing act is an essential component of the core STEM curriculum, making the lessons that much stronger. It takes a master teacher to integrate two subjects; however, STEM teacher leaders often need to incorporate three or four subjects in a single lesson.

Authentic STEM

Participants revealed that STEM is most meaningful for students when it connects to the world around them. Chad explained that STEM is showing students the world beyond curriculum or textbooks, stating, “Everything that you do, every day around you, is impacted by the things that you’re learning.” Participants described the importance of students having an understanding of using STEM for a broader purpose. Learning about authentic, real-world applications will prepare them for future employment and life skills.

Creativity

Participants agreed that creativity plays an essential role in STEM education. Chad described the use of creativity and STEM:

> It shows the kids that there's so much more to [STEM]. You can use that creativity, you can think outside of the box, and you can take these things that we are learning and do something with it that's meaningful and memorable to you.

Chad described creativity as the foundation allowing students to problem-solve within STEM. Several participants felt that STEM was involved in everything: It is integration; it is creativity; it is real-world learning; it is fun. The participants expanded on creativity's ability to ignite interest, problem-solve, and meaningfully engage students. Affinities are a novel way to understand the interconnectedness of STEM subjects and how they relate to the student, adding creativity and real-world experiences. Additionally, the teacher leaders understood that promoting creativity was part of the excitement in STEM lessons; as such, they incorporated creativity in innovative ways.

Summary

STEM teacher leaders exhibit an affinity to STEM related subjects, experiences, or teachers, family, or mentors. An affinity is a kinship of spirit or natural connection. Participants in this study revealed having an effortless connection to STEM topics, thus creating engagement with the subject matter. Affinities can entail connections with people, experiences, or, in the case of this study, the STEM subject. Supporting this theme were detailed descriptions of the affinity teachers develop with their students; the teachers' deep alliance with STEM topics led them to want to share this excitement with their students. This section comprises explorations of the sub themes of spark, students, and STEM connections.

Affinities describe the connections that STEM teachers have with their subjects. Participants revealed that STEM affinities created a personal connection between themselves and people, experiences, or STEM topics. The teacher leader affinity with STEM begins with a spark. The importance of a positive STEM connection with a parent, teacher, or experience inspires a passion for the subject matter and teacher leader. STEM teacher leaders' affinities emerged from the stories they shared about the subject. There is a substantial link between teachers and the students they teach. STEM teacher leaders develop unique student affinities that help connect learners to the topics they love. The collaboration and hands-on openness of STEM make it natural for STEM teacher leaders to develop deeper connections with their students.

Theme 2: STEM Teacher Leaders Use Integrated STEM Pedagogies

The second theme to emerge from the data was the realistic descriptions of how STEM teachers instruct their students. Participants described the excitement of using questions, hands-on learning, collaboration, real-world inquiries, subject integration, creativity, and reflection. Teaching with administrative support shows how affinity can encourage or discourage STEM. Consideration is necessary for the intricacy of teaching STEM and suggestions for overcoming it. Participants shared examples about STEM as a bridge for increased engagement with both exceptional and academically gifted students.

STEM teacher leaders are uniquely committed to using these pedagogies in their classrooms.

Table 5

Theme 2: STEM Teacher Leaders Use Integrated STEM Pedagogies

Pedagogies	Description
Inquiry	Participants teach with inquiry to allow curiosity, questioning, investigations, and improving from failures
Hands-On	Participants teach with a hands-on style to promote experiences which allow students to own their learning through manipulating materials, designing projects, or physically creating solutions
Collaboration	Participants facilitate opportunities for students to work in pairs or groups to solve STEM challenges
Real-World	Participants utilize high-interest topics, tangible manipulatives, and meaningful lessons that students can connect outside of their classroom walls
Integration	Participants connect and synthesize STEM subjects and/or non-STEM subjects to create embedded lessons that contain two or more subjects together
Creativity	Participants promote opportunities for students to bring new ideas into lessons and create a safe space for exploring and experimenting; It is also connected to STEAM, where the A stands for Arts, to incorporate visual and performing art extensions
Administration Support	The openness and willing attitude of school leaders to promote and allow STEM lessons
Messy	The untidy and chaotic STEM lessons which represent the exploration process of STEM
Reflection	Time in lessons reserved for thoughtful closure, planning next steps, and considering improvements
Exceptional Needs and Academically Gifted Students	Exceptional Needs refers to children who may have a hardship that prevents them from participating in class in a traditional way; Academically Gifted students may participate in lessons at an accelerated pace

Inquiry

A hallmark of a STEM teacher leader is using inquiry to launch and sustain lessons. Inquiry creates a platform of curiosity, encourages questioning, suggests solutions, and builds upon failures. All 10 participants used inquiry to various degrees within their classrooms. Concerns arose, such as professional development in how to use inquiry learning and how to connect it to the current curriculum.

Several of the participants acknowledged the use of phenomena to demonstrate inquiry because, as Rory explained, “Even if [students] don’t know what’s happening, they can explain it.” Rory provided an inquiry physical example of a jumping coin and glass bottle to demonstrate thermal expansion. Students can explain that the coin moved with the addition of warm hands to the bottle. The use of phenomena is an effective introduction to inquiry-based learning.

Several participants indicated a preference for using inquiry methods such as open-ended questions and allowing time for exploration. Some of the teacher leaders identified this process as students discovering that there are multiple ways to solve a problem. The teachers have found they can use open-ended questions to promote student thinking without giving them the answer. Inquiry puts the students in control, providing the space, materials, and time to explore, ask questions, and experiment.

Multiple participants mentioned an inquiry-based, hands-on project, a decimal Christmas shopping problem in which students use real store flyers to complete holiday shopping. The catch is that the students have not learned how to add or subject decimals, requiring them to figure it out as they work through the task. Barbara related, “They [the students] would naturally ask . . . 'What do I do with this decimal?' and then you answer and they're like, 'Oh, okay.'" The exercise was an opportunity for students to experiment and discover on their own. STEM teacher leaders commit to utilizing inquiry methods for their students, giving them ownership in the discovery process.

Hands-On

Participants provided examples of project- and problem-based, hands-on learning activities. Marta discussed problem-based projects, like using a robotic bug, Hexbug, to complete a student-designed maze. One of Fern's examples included creating a turkey transporter to move a turkey from Point A to Point B within specific parameters. Many participants explained hands-on learning as a favorite classroom strategy for students to problem-solve without formal instruction by creating their own solutions.

Some teachers chose to make a physical connection to the science lesson, The Cardiac System. Rory recalled the students going for a run and then focusing on the guiding question, "What's your body doing when you run?" Students have to describe what happens to their body when it is in motion. Participants agreed that crafting hands-on lessons allows students to become personally involved in the learning process. Hands-on activities enable STEM teacher leaders to incorporate student engagement into their lessons.

Collaboration

Collaboration allows the students to work together in teams or pairs to address challenges. All of the participants promoted collaboration in their classrooms, with many identifying building the expectation for collaboration as key to classroom success. Chad uses an accountability talking points poster (including phrases such as, "I do not agree with you because I think…") for students to practice with different activities. Chad stated,

> I think their peers have kind of realized that it's just that mutual respect, that it's okay to disagree. We might not always agree and get along all the time. But if I'm going to disagree with you, I'm at least gonna justify it. I'm going to tell you why.

Participants viewed collaboration as a critical skill and a life-long lesson. Students should know how to talk with purpose, be confident, and provide supporting evidence. STEM teacher leaders construct opportunities for their students to collaborate in their lessons, and they are committed to facilitating these conversations around STEM.

Real-World

Despite real-world learning being one of the most often-cited areas of excitement, participants identified it as the section most often cut due to time constraints or stress from testing. Real-world learning commonly consisted of a high-interest topic, tangible manipulatives, and the meaningfulness of outside application. Chad explained why real-world learning was so powerful for students:

> It matters because it makes their learning tangible. They can take what we've learned and apply in a real-world type of way, or they can create a product that would model something that they may do in a future career or future line of something they're interested in.

Real-world learning connected students with the standards they needed for present understanding and future opportunities.

Participants agreed that real-world lessons should be meaningful. Winnie gave an example of comparing the design and safety features of NASCAR racing vehicles with passenger cars. The culmination of the product involved students building and racing their cars in class.

In another example of a real-world activity, Minerva introduced current topics to her students, such as energy drinks or vaping, and then connected the topics to her science human body unit. She wanted students to be aware of how real-world dangers aligned with curriculum standards. The participants agreed on the importance of real-world activities as they suggested engaging ways to connect student interest with content standards in the curriculum. STEM teachers are unique in that real-world activities create student ownership and lesson buy-in.

Integration

Despite expectations to integrate subject topics, few participants recalled having received specific support in learning how to implement integration. Barbara’s school leaders instructed her to integrate and use hands-on learning, but she had never heard of STEM. Rory had learned how to integrate topics in her preservice studies; however, it took many years of teaching to learn how to integrate seamlessly and effectively.

Participants wanted students to comprehend that all of the STEM subjects are interconnected. Rory gave an example of integration as science teachers naturally embedding ELA instruction with evidence gathering, thereby connecting the two subjects. Chad did not fully understand integration until he started teaching, describing it as “more picking it up in the field, for sure, because you’re in that situation where this is the real deal; we're in the ballgame now." Fern had fully integrated her STEM teaching with multiple subjects. As an example, she shared,

> We're incorporating informative writing and ELA with that, and then in math, they are taking an animal from both of the ecosystems that they research and they are building a cage using . . . volume formulas and ways to transport that animal to a made-up animal hospital in a different location. . . . They also have to calculate the distance, which also incorporates some of our force in motion, like calculating speed and distance.

Participants expressed a desire for more professional development to ensure they integrated all the standards that students needed. STEM teacher leaders often incorporate two or more subjects into each lesson, far more than a non-STEM teacher. Integration is an often-difficult responsibility unique to STEM teacher leaders.

Creativity

Creativity is a critical component in problem-solving necessary for STEM experiments and adaptations, as explained by participants. STEM teacher leaders have to be strategic to create opportunities for students to expand their creative problem-solving abilities. The 10 participants agreed that creativity is necessary for STEM problem-solving; however, they varied in their comfort levels with implementing creativity. Some of the teacher leaders reported that assigning expectations and grades for creativity was difficult; also, creativity is not a part of standardized testing. Too often, teaching creativity yields to teaching testing standards.

Participants described the importance of allowing space for creativity. Chad noted how STEAM (Science, Technology, Arts, & Math) supports the other subject standards in his classroom and promotes students' ownership of tasks. The participant said,

> I want to give them things that [provide] that outlet for their creativity because the group I have this year is extremely creative. . . . I think being able to do more STEAM activities, just to see that creative piece, and letting that shine more.

Creativity allows his students to see him not just as a teacher, but as a person.

Winnie scheduled unstructured time for students to make room for creativity. When students enter the classroom, they can self-select STEM bins and create. The bins contained various building objects, from recycled materials to building blocks. Winnie explained how her STEM bins creatively supported skills for struggling students by creating math challenges where students skip count items or construct a structure worth a specific point value. These STEM bins are a creative outlet to practice concepts as students solidify objective standards.

Participants acknowledged the struggle of feeling confident using creativity and defining what it looked like in their classrooms. Teachers were candid about recognizing the need for creativity yet feeling unsure of how to support it strategically. Participants expressed discomfort in feeling adequately "artsy" in their STEM teaching. Rowan described the difficulty of students engaging in the creativity of an assignment, but not knowing how to shift from creativity to attaining a solution. The challenge is in using creativity and allowing students time to problem-solve while making progress on a finished STEM product. STEM teacher leaders recognize the value of rising to the challenge of adding creativity because it creates ownership by the student learners.

STEAM

Like creativity, participants reported various comfort levels in adding the A (art) into STEM (i.e., STEAM). There was also confusion about what qualified as an example of teaching with STEAM. Most participants acknowledged the meaning of the term but were unsure if they had authentically incorporated it.

Participants shared examples of using STEAM in their classrooms. Minerva stated, “I feel like the kids really enjoy when I can get the art integrated with the science. It keeps them a lot more focused; they’re having more fun.” Fern gave a strong example of STEAM:

> When we were teaching heat transfer, it was right around Halloween time, so I had the kids create a portrait . . . where they had to represent conduction and convection and radiation, all in one portrait. So, they would have the witch touching a cauldron for conduction, and then convection was inside of their pots. Radiation had the sun, the fire, or the heat coming off the campfire. . . . I’ve been trying to incorporate a lot of art into STEM, or STEAM, this year.

Fern decided to add STEAM because she noticed that her class was very interested in drawing. She wanted to incorporate that enjoyable creative process to connect students with her science lessons.

Not all participants were comfortable with STEAM. Barbara expressed anxiety with STEAM, which she described as “nerve-racking.” Several participants were willing to add STEAM but would feel confident with more professional development.

Administration Support

Participants explained that the level of administrative support determined how willing they were to utilize STEM in their classrooms. The veteran participants were more likely to add STEM elements without asking for permission. The newer teachers worried about pleasing their administrative leaders but had a stronger background in implementing STEM.

Marta explained that the administrative use of Title I funds to create whole-day planning sessions allowed her to be strategic in brainstorming the integration of language arts and STEM ideas. When she could plan the entire semester for language arts, she felt more confident in incorporating science connections with STEM into her scheduled plans. Minerva recalled a past administrator who provided the time to support STEM and the resources to purchase materials. The administrator mandated that each class have a weekly hands-on science experiment. STEM teacher leaders are unique in that their lessons have many components (e.g., creativity, hands-on, necessary materials) that require administrative support to continue.

Messy

All participants agreed that messiness is part of the STEM process. Marta explained that the mess comes from the materials and construction of STEM, because part of the learning process is promoting exploration. Winnie described the mess as worthwhile. Minerva, too, identified the mess factor as necessary:

> I think the messier you are, the better they're going to remember, like with hands-on stuff. . . . In the beginning of the year, we're doing physical and chemical changes, and we get to pour the vinegar and the baking soda and add food coloring and make it smush out of the test tube. They would want that every single lesson if I could do it.

For Minerva, getting their hands dirty made the lesson more meaningful for students.

Some participants equated "messy" to the teacher being able to cede some control. Rory explained,

> You see my room. . . . It is messy. It's loud. But you just gotta let go. . . . I think that's where teachers . . . especially traditional teachers, they have a hard time and you've got to let go, and just let the kids do it. It just depends on your personality. If you are one that likes control, this is hard for you to do. Me, well . . . we just roll.

Rory described her STEM class as a space where she has promoted student choice and relaxed some of her oversight. Ceding control, however, can be difficult for teachers. Winnie expressed concerns that a messy room might suggest the teacher is not in control, leaving school leadership unwilling to support STEM.

Participants suggested using a blueprint in the STEM process to curb the messiness. Chad said, "I feel like if you're doing STEM, you do want a blueprint. . . . There's always something that you don't plan for, the unexpected, and you don't know exactly how the students will respond to it." Chad explained that teachers need a plan to move forward with STEM yet must remain flexible when the unexpected occurs. Participants agreed that although STEM is messy, meaningful student engagement was worth the mess factor. STEM teacher leaders are unique in that their lessons require more mess than most subjects. Teachers must be prepared with a plan of organization to keep their lessons moving forward without distractions or messy detours.

Reflection

All participants acknowledged that reflection promotes closure, providing time to reorganize the next goals in STEM teaching experiences. The 10 teacher leaders expressed regrets in not having more time for reflection activities. Rory's reflection occurs at the conclusion of the lesson, when she focuses on setting new goals. Marta described implementing a whole-class discussion during a STEM activity to reflect on improvement:

> They were making those pathways for the [robotic bugs], and there was one group where one girl was just kind of sitting there, doing her own thing. So at the end of the day, we talked about how we can collaborate better with our partners. And she suggested that next week maybe they have specific roles in the group and jobs for each person.

Marta's students positively reflected on adding specific leadership roles to improve their collaboration process.

Chad described that reflection builds accountability among students' efforts, teaching students how best to organize their thoughts to explain their thinking. Chad was adamant about how critical the reflection process was for both teacher and student growth. He explained that reflection helps him see if someone is having a problem and allow students to recognize what they have learned.

Leigh Dell described her class reflection journals as interactive notebooks. Each journal has a color-coded rubric for students to assess how well the lesson went and rank their understanding of the concept before and after their STEM project.

Participants lamented that time constraints often prohibit the reflection process. Rowan explained that reflection can be a challenging process for students as well as adults, with neither group motivated to admit mistakes. Protecting time for reflection helps students understand that the learning process is never complete and allows room for continuous improvement. Reflection is a means to enhance many lessons. A difference with STEM is that teacher leaders' reflections are never truly complete. There needs to be time for the reflective processes of assessment, goal setting, and next steps to continue the STEM curriculum.

Exceptional Needs and Academically Gifted Students

Exceptional Students

All participants shared an impactful story about STEM bridging the learning in their class for all students. Chad recognized that STEM allows for student success, no matter the academic level. He said, "I feel like [STEM] can be very beneficial in bridging those gaps. And it can make those students who may typically struggle realize, 'Okay, I can be successful. I can use what I've learned in a powerful way.'" Rory believed that STEM "absolutely" met EC students' needs, sharing a story about a student who was typically disengaged: "That is when he would shine, you know, because that kid could STEM it up. He could build. He had a vision. That was his shining point, and that was awesome. . . . He got to shine." Participants agreed that STEM allows opportunities for all students to achieve classroom goals.

Academically Gifted

STEM challenges can become problematic for gifted students who are accustomed to assignments being easy. Minerva said that even the gifted students sometimes turn into "deer in the headlights, not knowing what to do next" when confronted with a STEM challenge. Chad noted his challenges with academically gifted (AIG) students in STEM:

> The [EC students] shined brighter than my higher flyers because [the AIGs'] models that we made did not succeed and they couldn't handle it. They could not

> handle that they had spent time and effort and put it into something and it was not the best.

Chad described this instance as a good moment as an educator because he could see that he challenged everyone at their appropriate level.

Barbara stated that the AIG students were sometimes the most frustrated with STEM lessons. However, she remarked that shared leadership through STEM is a critical collaboration lesson for all students. Participants agreed that STEM pushes all students, including AIGs, out of their comfort zones in ways that mimic the real world.

STEM as a Bridge

The teacher leaders found that EC students saw things in different ways. Each participant had stories of EC students problem-solving or helping gifted students learn something new, or the resilience of all students working together. Participants spoke of STEM as a bridge for all learners to find success. Winnie explained, "[STEM] levels the playing field; it puts them on the same footing. Because, again, they can see it their way, and there's no wrong way to do it." STEM provides a space for all students to bring possible solutions. It promotes students who may not be successful in traditional academic subjects to lead. Leigh Dell found engaging in STEM with multiple student abilities works because all can contribute to their ability. All students add to STEM project success but do not necessarily take the same path. When Leigh Dell used STEM activities and escape rooms, her two high-needs students were able to participate:

> You could see the enjoyment on their faces. . . . They could participate like everybody else. . . . I think that's really when my spark started. I was able to reach

> everybody. I mean, even my AIG kids—we were all in the same room, and we were able to all work on the same activity.

Leigh Dell's story shows that STEM creates a platform for active participation by all students.

When Barbara began to watch an AIG teacher use STEM, she realized that her EC students had the same ability to reach the goals. She said, "The more I implemented STEM-type things…or just different ways of thinking, I would see my EC kids become the leader, so that was really nice to see." She continued with an example of how an EC student became the teacher, leading a very high-AIG student through Code.org.

> I have the picture of those two working together and him pointing something out for her. . . . Then they kept going to him for help. This is a child who's never felt successful with anything, so I just—that's why we do try to incorporate it when we can.

This example from Barbara illustrates how an unlikely academic pairing led to success through STEM.

Rowan described an activity called "The Bridge of Muck," where students had to build a bridge with recycled materials to escape alligators. While problem-solving solutions, the students became concerned for a classmate with mobility challenges. Rowan hesitated to interrupt the learning because she was unsure which direction this brainstorming session would turn. She had nothing to worry about, though. Her students devised a plan that included making a chain to cross the "muck." Rowan described watching her students put their arms around the EC student and holding him up to cross the bridge. These were first-graders, the type of empathetic leaders who only saw solutions and left no person out in a STEM challenge.

Literally and figuratively, STEM is a bridge for all students to succeed. Every teacher wants to facilitate growth with EC and AIG students. The uniqueness of STEM teacher leaders is that they have a fluid subject that promotes the use of support. As a result, teachers can easily make the STEM challenges more comprehensive or build in reinforcements to help students with disabilities. STEM subjects provide a space where all students can contribute, showcasing different talents that may not arise in a typical class situation. STEM teacher leaders create a safe environment in which all students can contribute and grow.

Summary

The second theme of teaching with STEM creates a comprehensive picture of the best pedagogies. Describing each pedagogy is with vivid, relatable experiences that create a lens into the STEM classroom. The authentic views of administrative support and the messy aspect of STEM show the challenges STEM teachers face. The most uplifting aspect is how STEM supports students with unique needs, allowing teachers to create scaffolding opportunities for engagement. STEM teacher leaders are committed to the use of these pedagogical tools to enhance student learning and participation.

Theme 3: STEM Teachers Function as School Leaders by Modeling Innovation Through STEM

The participants discussed their practices and experiences to describe an authentic STEM teacher. The STEM practitioner is committed to professional growth, with experience in preservice STEM as well as participation and leadership in professional development. An authentic STEM teacher advocates for student improvement through locating materials, completing research, and using data. An area of growth that arose was the need for improvement with community stakeholders.

Table 6

Theme 3: STEM Teachers Function as School Leaders by Modeling Innovation Through STEM

STEM Teacher Leader	Description
Pre-Service STEM	Participants experiences with STEM in college before becoming a STEM teacher leader
STEM Professional Development	Specialized training for participants focused on STEM and leadership best practices and support
Leading Professional Development	Participants experiences with facilitating professional development which includes STEM pedagogies or leadership to influence student achievement
Materials and Supplies	Participants experiences with collecting supplies for STEM lessons through grants, donations, school leadership, or purchases
Advocate	Participants describe their public support for STEM and student growth
Research	Participants conduct research to remain current in STEM through understanding Next Generation Science Standards and professional conferences
Data Usage	Participants describe the use of assessment data to create remediation plans and accelerate student growth
Community Stakeholders	Participants describe limited support from community church, business, and local leaders

Pre-Service STEM

Participants had varying levels of preservice STEM experiences. Most participants had graduated years prior, when STEM was not something mentioned in their college training. Fern explained, “I didn’t even know that [STEM] was a thing.” Even some of the more recent graduates did not recall STEM used in their coursework.

Several of the younger teachers related STEM experiences in college. Barbara, a 2012 graduate, had one professor who assigned every project in a STEM format, which she found highly challenging. A significant project that required a STEAM-integrated lesson ultimately prepared her for the STEM classroom.

Shelby was the only participant who graduated from a STEM-concentrated program, a concept that drew her to the college. However, it was not until she was engaged in the program that she realized how “cool” the opportunity was, compared to her peers in traditional education programs. Her coursework included instructional technology, engineering, and courses with STEM-integrated themes. Although students completed the basic educational courses, they doubled up in math and science (non-pedagogy) courses to have a strong background in these areas. Shelby found the engineering class helpful as they went through the engineering design process with possible STEM activities. She provided an example of the engineering design notebook and the creation of standards-based STEM lessons. Standout real-world scenario STEM lessons included a robotic bug maze, marble tubes, and an oil spill clean-up. Shelby credited her educational background for preparing her with many possibilities of classroom STEM implementation.

STEM Professional Development

TLMS (Teacher Leader Model Standards, 2011) described school leaders as those who seek professional development. It is critical to access and use current research to improve educator development and student learning. Participants shared accessing STEM professional development through administrator requests, grants, and social media. STEM teacher leaders must be resolute in identifying opportunities for professional development because there are limited offerings.

Participants who attended administrator-assigned professional development were pleasantly surprised to find inspiration in the workshops. For these participants, this was also their first experience with STEM. Participants described the workshops which inspired them to complete her own STEM research and continue their professional growth.

Grants

Several participants had experience with university grants for STEM training. Chad had an enriching experience through a grant with Wake Forest and the University of Texas, which focused on project-based and inquiry-based learning. The standard focus was math with the integration of science and social studies. The grant was a multiyear plan that presented project-based lessons, teacher observation teams, and a design team. Chad, who participated in all 3 years, described the third-year design team as highly meaningful for his sustained growth in STEM. Chad expressed that one of his biggest takeaways was learning how to take a standard and plan backward. They would pick apart individual math standards and create an inquiry-based problem designed to be complex enough so that a class would grapple with it for a few days. Then, students would submit a final solution they could explain. Chad stated that his students were very motivated and focused, as was needed to succeed in these projects.

Marta participated in a STEM Teacher Leadership Next Steps workshop, finding the most helpful part to be examples of questions to ask students while working on STEM projects. Before the workshop she explained, “I didn’t know exactly what questions to ask to help guide them, rather than give them the answer.” Rory participated in the Community of Inquiry STEM Teacher (COIST) group. The COIST meets once a month to prepare for a fifth-grade science lesson. Teachers work together and observe each other teaching the lesson, after which they reflect and share suggestions to continue to enhance the lesson plans. This process has been significant and inspiring for Rory, who said, “I’m just loving every second of it and I just can’t get enough.” Persistent teacher leaders have found opportunities to continue their professional development.

Social Media

Participants identified social media as one of the best ways to locate and participate in STEM professional development. Rory uses Twitter to connect with science teachers who instruct with similar phenomena to share ideas. Barbara found teacher Instagram accounts a great way to keep current in education. For example, she follows one STEM teacher who posts informative how-to lessons and tips. Participants found it empowering to read a current practitioner’s suggestions on social media, which inspired their learning.

Conferences

Several participants serve the school as personalized learning ambassadors or digital learning coaches. These roles include having access to STEM materials and professional conferences. Barbara stated that attending the International Society for Technology in Education conference introduced her to many STEM connections. The participants cited the North Carolina Technology in Education Society (NCTIES) as an excellent resource for ideas and connecting with others. NCTIES provides opportunities to learn from current practitioners, as well as student showcases.

Leading Professional Development

Most participants act as instructional leaders, as they facilitate professional development within their schools. Several participants reported having leadership roles, including serving on the School Improvement Team that selects professional development opportunities or informally supports peers. The roles of digital learning coach and personalized learning ambassador require a teacher leader to share best practices and innovations in digital or personalized learning.

Many participants serve as the personalized learning ambassador in their schools. Personalized learning is a data-based instructional strategy that revolves around student choice in conjunction with STEM. Rowan, also a personalized learning ambassador, helps teachers adjust their schedules to add STEM and personalized learning. She described how she assists teachers in setting up these systems for classroom and remote learning. She is currently helping a beginning teacher with seating assignments and choice boards. The personalized learning coach is a critical role in current teaching to allow students choices and ownership in their learning.

Shelby serves as her school’s digital learning coach. She explained that she tried to keep away from mandating expectations, instead creating a PLC guided by teacher needs and suggestions. She described learning from her teachers as well as coaching them about incorporating technology and STEM. The teachers challenge her by asking about new things she has never heard of, requiring her to conduct research. Shelby feels that this professional development facilitates improvement in instruction.

Rory works as a digital coach, leading teachers in digital instruction. However, she does not feel she is a STEM leader because her role is to lead in the classroom. Rory struggles with recognition as a school-wide leader; however, she is implementing staff professional development and is the problem-solver for personalized learning challenges. Barbara also expressed leadership concerns. Even though she is on the school leadership team and serves as a digital learning coach for her school, she doesn't feel like a leader. She said, “I’m just a digital learning coach. I’m not like a natural leader. It’s . . . very hard for me to be a leader. That’s something I need to work on.” Barbara has received multiple opportunities to hold leadership positions, which she appreciates because these force her to grow. STEM teacher leaders often function as digital and personalized learning coaches for school-wide support because they are uniquely suited to use their pedagogy background to share these strategies.

Materials and Supplies

Materials and resources are a necessary part of STEM teaching. However, the teacher leaders differed in how they obtained materials. Participants used grants or professional development, asked school leaders, relied on family support, or secured materials themselves. All participants agreed that the lack of resources makes teaching STEM a challenge.

Grant and Professional Development

Several participants described completing grant applications to access resources. Rory received STEM professional development that allowed participants to utilize STEM kits in their classrooms. She identified this as an amazing opportunity because the materials are expensive and difficult for a teacher to access. Chad implemented resources that he created at his Wake Forest/Texas STEM Professional development session. Having these resources ready to implement has saved him time and energy. Rowan and Barbara described grant writing to fund needed supplies, such as robotic technology or roller coaster materials.

Hunt

Multiple participants admitted to relying on a “free” option by requesting supplies from school families, friends, and personal family. Outside of the STEM engineering kit, Rory has had to scavenge for materials to use in her class. She described the process as “scrounging” to find materials or building affinities with people so she can ask them for things. Participants rely on a network of affinities, needing the courage to ask others to locate needed resources.

School Leadership

Several participants described cultivating relationships with school leadership, so they feel comfortable to ask for resources. Minerva explained how a past school leader stocked a science project laboratory, so she had access to equipment for her STEM lessons. Leigh Dell pitched ideas for STEM activity materials to her principal and asked for permission to use funds to purchase STEMscopes, a curriculum program. Building open communication with school leaders creates an opportunity for participants to present their needs and advocate for STEM resources.

Family

Participants described how their personal and school families supported their STEM resource and material needs. Winnie obtained resources from her home, personal monies, or a gift from her spouse. Although receiving family gifts of STEM materials may sound odd, the trend was apparent through this research. Barbara relied on credit cards, money from her grandmother, and sharing an Amazon wish list with her family to collect materials. Shelby asked classroom parents to send in recyclable items like paper towel tubes for projects.

Self

Participants often relied on themselves to secure STEM materials. Marta described access to college STEM kits, which she found to be useful. She mentioned an upcoming landform experiment that requires the purchase of food items, which was her responsibility. Rowan remarked that her leadership role with the school recycling team helped her secure materials to use for future STEM projects in her classroom.

In response to questions about resources, Leigh Dell explained, “If I do not have them, I buy them,” pantomiming swiping a credit card. She stated that working at a high-needs school means having a greater need for these supplies, and that students would not have access to these opportunities unless she purchased the materials herself. Many times, curriculum funds go to updating reading materials, with little left for science, math, and technology manipulatives.

Advocate

Participants described advocating for students, teachers, and political change for education. The tone changed to one of passion, as teachers explained the reasons behind their advocacy. Many participants did not feel they were true advocates, but their words were powerful as they expressed their support of groups with needs.

Students

Participants discussed advocating for their students through CASA, supporting student needs, and reinforcing social-emotional learning (SEL). Through her grade-level CASA meetings, Marta explained, she advocates for her students daily. She supported student evaluations for special services, explaining each step to the students and parents. Rory is a vocal advocate for her students. She shared, “I’m going to speak on what their needs are. . . . My idea of equity . . . is that you’ve got to figure out where they come from so that you know what they need. . . . It is not the same with any kid.” Rory is prepared to advocate for her students because she has developed affinities with them and is aware of their needs.

Fern described her role as an advocate with a focus on student SEL. Her growing awareness of SEL inspired her to create a Friday check-in survey. In this Google Form, students can rate their week, select an emoji to represent it, and describe the reason in the text box. This way, Fern has become aware of situations, allowing her better to support her students.

Teachers

STEM teacher leaders are advocates for peer teachers in their school communities. Through Barbara's role as a digital learning coach, her advocacy mission is to help staff understand that technology is not a babysitting tool, but it can enhance learning. Minerva described speaking at staff meetings to advocate for science instruction in the lower grades. Science is a non-tested subject in K-4, so she worries the school could drop it for tested subjects like math or reading. This puts pressure on Grade 5 science teachers to fill any academic gaps and introduce new standards. Minerva has found her efforts to be fruitful, based on the difference she has seen in science engagement as she advocates for teachers to use hands-on science methods. Minerva, like many other participants, is focused on providing support so that teachers can deliver the highest level of instruction to their students.

Political

Several participants have become involved in educational politics. Marta described her efforts in staying up to date with legislation and political movements in education. She explained, "I don't like politics, but I try to stay informed on the changes that are happening. When I'm talking to parents . . . I want to sound like I know what I'm talking about." Minerva described her advocate role in a professional teacher organization. As a school representative, she took a personal day to drive to the State Capitol and protest for legislative change. Minerva explained her process: "[I] held up my little sign and felt like I was really . . . effecting change, and I was making an impact, and things were going to be brilliant the next day, and then I realized that it didn't really go much of anywhere." Participants shared skeptical views on what they thought about education and politics. Several have been disheartened, yet noted educational politics as something to be aware of, including the effect on their classrooms.

Research

teacher leaders are becoming active in current research efforts. Participants described their STEM research efforts as understanding Next Generation Science Standards (NGSS), professional conferences, and research opportunities. Rory struggled with the test-driven focus in education and using the standards with STEM. She has completed self-research on NGSS, which NC did not adopt. She explained her frustration: "What they're tested on and what they're getting here is two different things. If we went to the national standards, the NGSS would rock it. . . . We're feeding them facts. . . . That's not the world they live in." Rory feels the frustration of meeting the academic needs of students versus meeting school testing standards. STEM teacher leaders strongly advocate for further curriculum research.

Conferences

STEM conferences and professional development tend to be singular events; as such, the participants use these sessions as starting points for their research. Participants discussed attending professional conferences that encouraged them to continue their research, even after the sessions concluded. Several STEM teacher leaders relied on NCTIES to keep them connected to current STEM professional development and provide resources.

Limited

Research was an area in which many participants had limited experience. Some of the teacher leaders lacked time to devote to research. The participants with the most growth experiences in research are involved in a group or serve as digital coaches, receiving free admission to these conferences. Participants seemed embarrassed to admit having limited experiences with STEM research, but all acknowledged the importance of research in their professional growth.

Data Usage

Many of the participants used data to drive instruction. Marta described using her testing data to create remediation plans for specific standards. Fern used data to drive instruction to see which students needed help and who needed to be accelerated. She also used her data to build intervention groups and set academic goals.

Assessments

Participants spoke about the importance of formative assessments. Chad described how formative assessments allowed him to identify something small that a student did not comprehend and now would be easily fixed. He stated the importance of the process: "I'm using [formative assessments] for my instruction . . . to show me where my weak areas are, and where I need to improve." Formative assessments help Chad quickly identify student areas of improvement before moving onto a new topic. Barbara described using formative assessments, annotative notes, and exit tickets to gauge students' abilities quickly. Barbara used these data for ability and mixed-ability groups so she could focus instruction on specific skills.

Remediation

Participants identified the remediation process as key with the use of data. Rory went further, separating her assessment standards into sections to see which group of students was still struggling with a specific standard. She then separated students into groups and remediated. For example, her ecosystem assessment comprises three sections: characteristics of an ecosystem, ecosystem food chains, and affinities of plants and animals. Using this method allows Rory to drive instruction with data.

Challenges

Overall, participants remarked that the data process was important but identified challenges that kept them cycling between data assessment and remediation. Rowan described assessment expectations, explaining that her grade level assesses data, but the remediation piece happens as best as it can, when it can. Minerva shared that her data planning can be isolating because she is the only self-contained science teacher in her grade at her school. Teachers of more common subjects (e.g., ELA) can have conversations and strategize together. Leigh Dell mentioned this situation, noting that the priority subjects for data review are reading and math, with science often skipped.

Community Stakeholders

Participants varied in their involvement in community and family support. As discussed earlier in the chapter, participants identified family support as instrumental to student learning. However, a few Title I school participants described school wide initiatives that involved community stakeholders. When pressed to name the community stakeholders, participants often struggled to identify churches, businesses, or community leaders who supported their schools.

Summary

The authentic STEM teacher leader increases student learning by focusing on professional development, advocating for students, researching best practices, and analyzing data for improvement. The common theme was that teachers did what they needed to help their students. Often, the participants were passionate about their involvement and commitment to making their classes better for students, as well as assisting peers in joining their STEM efforts. Overall, this is the most critical area for STEM teacher leader growth. There is much to be gained from fostering positive affinities with stakeholders and families. Affirmative support with community stakeholders will create reinforcement through advocacy, mentors, or materials.

Theme 4: STEM Teacher Leaders Face Challenges and Barriers That Limit Their Implementation of STEM Approaches

STEM teacher leaders discussed legitimate concerns when implementing STEM. Participants candidly described areas of limited control, such as administrative support and testing parameters. Concerns about resources and a lack of time or professional development led to suggestions of how authentic practitioners have approached these challenges.

Table 7

Theme 4: STEM Teacher Leaders Face Challenges and Barriers That Limit Their Implementation of STEM Approaches

Challenges	Description
Administration Support	Participants describe the uncertainty they feel with their administrative leaders' support of STEM
Testing	Participants struggle with the test-driven school environment and teaching with pedagogies that they feel are the best practices
Messy	Participants explain that the messiness of STEM is a deterrent because of the appearance of lack of control and physical clutter to contain
Resources	Participants explain that lacking materials and the expense of resources is a STEM challenge
Time	Participants describe the need for protected time reserved for necessary STEM training and time for students to complete STEM lessons
Lack of Professional Development	Participants describe the limited professional development available

Administration Support

Winnie, who teaches at a school with a new administrator, struggled to recall a recent problem-based learning task. She explained, "I'm still kind of learning what you can even get away with and what you can't." This was a common sentiment: Teachers were unsure how supportive the school leadership would be of STEM-based learning. As discussed, STEM-based learning can be messy, loud, and expensive. Teachers were divided between pleasing their administrators and teaching with STEM. Participants agreed on the amount of STEM engagement based on what they could complete with administration support. Because STEM lessons require unique materials, fostering positive administrative support is crucial.

Testing

Testing is an area where participants felt torn between the pressure to be successful with testing and spending time with STEM. Rory described her testing struggle, saying, “While this [STEM] is all fun and good, if you’re at a proficiency-driven school and we’re still sitting at about 50 to 60% [proficiency], is this the most effective way?” Rory struggled with navigating what was best for her students and the test data-driven culture of many schools.

There is a heightened expectation that test scores must continue to rise. Winnie stated, “Then there’s this testing . . . you better look good.” Even as a primary teacher who does not have EOG tests, she still feels the pressure of preparing students for tested material. With a test-driven focus, participants felt stress about appropriately incorporating STEM lessons. STEM teacher leaders are in a unique position to advocate that implementing STEM is part of preparing students for testing success.

Messy

Winnie confessed that the messiness has kept her from using STEM. She explained, “It is messy, you know, and then there’s this factor of control,” referring to teachers’ difficulty to cede control in their classroom. Fern believed a primary reason people are afraid to try STEM is that it is too messy or looks like playtime. She tried to overcome this worry by modeling with teachers how to appropriately use STEM through her class lessons.

When Rowan started using STEM, the only materials she could afford were recycled or trash, and she felt like her class was a “hot mess.” Rowan stated, “At one point in time, [STEM materials were] all sitting on their desk or under their desk, and it was terrible.” She has since started giving students a large plastic tub to return all materials when done, which has improved the mess factor.

Resources

Participants described the lack and expense of resources as a reason to avoid STEM. Rowan said she practices what she preaches with her Earth Day philosophy: “We’re always talking about recycling and reusing and the things you can use instead of having to go buy stuff.” Rowan’s concerns continue, however, because her school has high-needs students and she is aware that families do not have the funds to purchase materials. Rowan has created a workaround, which she shared: “Any project we do . . . I always tell them, ‘I’ll give you extra credit if you can do it without having to go buy stuff.’” She taught this process by taking walks outside and experimenting with using items found in nature. She wants her students to achieve the ability to build what they need with limited resources.

Rory stated that the lack of materials can limit projects or create new challenges; when she cannot assemble the necessary tools, her students make do with what is accessible. Chad either requests parents to send in supplies or purchases them himself. He explained that many STEM materials can only be used once, which creates a never-ending cycle of need. Fern stated that the individual items are not expensive on their own, but purchasing them for large groups of students becomes prohibitive. STEM teacher leaders must be creative as they problem-solve their resource needs.

Time

Several of the participants who serve as digital learning coaches expressed that time was a factor in training teachers to learn the newest strategies for supporting education. Rowan stated, “Some teachers aren’t interested in [digital learning]. I’ve had some backlash. . . . I had to back away, but the ones that are interested in it, I tell them I’ll help them any way I can.” She offered to help a teacher with STEM activities, and the teacher reported to the school administration that she felt harassed and peer-pressured to participate. Defiant refusals or passive-aggressive responses demotivated digital learning coaches to continue their pursuit of unwilling participants.

Marta described her selection for a Community of Inquiry study in which she would earn a stipend and paid time off for professional development. However, she felt it would be difficult to take time off for the training. Marta expressed, “I just couldn’t take that many days off this year. It’s my first year in this grade, and I have a lovely energetic group, and I just don’t want to miss that many days.” Marta was willing to take part but was unsure if she could commit to the professional development due to the time away from her classroom.

Barbara described a STEM-enriched force-and-motion unit that concludes with students constructing marble roller coasters. The STEM roller coaster project engaged students, enriched vocabulary, and allowed them to build problem-solving skills; however, the district cut the unit to make time for testing preparations. Rowan described a complicated STEM parade project with multiple steps. Her grade level had started the project, but the district ordered them to "just stop it. . . . You have to the end of this day and you have to be done, and if you're not finished, oh, well." "Cutting off" was a concept with which several participants struggled: determining how to end student engagement when time is limited.

Lack of Professional Development

Many participants described the frustration of having to seek out professional development. There is no true dedicated STEM curriculum specialist, and the district-level staff are focused on middle and high school STEM support. Barbara provided an example of a teacher returning from a conference, excited that she had learned how to create a digital escape room. Barbara's irritation was clear with her unspoken response, which she shared: "You mean like that faculty meeting I did earlier in the year that no one listened to?" Frustrations with the lack of peer engagement and commitment, along with limited professional development options, are a challenge for STEM teacher leader participants.

Summary

In their interviews, the STEM teacher leaders portrayed the difficulties they faced. Challenges ranged from administration support to securing materials. STEM teacher leaders identified obstacles with possible solutions, showing themselves to be courageous and willing STEM advocates.

Chapter Summary

In this chapter, I presented the themes that emerged through data collection: STEM teacher leaders exhibit an affinity to STEM related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning, STEM teacher leaders use integrated STEM pedagogies, description of an authentic STEM teacher, and challenges STEM teachers face. I provided details from each participant's story to create a shared narrative. I found that the more experienced teachers had more to say; therefore, their narratives are more prominent. However, each participant contributed to create a clear representation of STEM teacher leaders. Linking the details shared in Chapter 4 prepares for what is next in STEM teacher leader research.

In Chapter V, I return to my conceptual framework, provide a detailed answer to each research question, and share conclusions and possible recommendations for multiple audiences. I connect the participants' stories into implications for future research as well as application in schools and by educational leaders. These findings create a powerful plan to continue to grow STEM.

CHAPTER V

CONCLUSION, IMPLICATIONS, AND CLOSING THOUGHTS

Kelley and Knowles (2016) found STEM teacher leaders act as critical change agents in their schools, providing creative and academic support to students and communities. This study was an exploration of STEM teachers' methods of instruction and leadership roles. Participants discussed their focus on and passion in improving their craft. Additionally, my findings indicated that the participants believed in the power of STEM to influence children's futures, as did Kelley and Knowles (2016). Some participants taught STEM without having the administration's support (or, in some cases, awareness); however, they strongly believed in the opportunities STEM provided their students. My findings emerged from the data analysis that explained the need to encourage STEM teacher leaders because of the innovation and student engagement they bring. This STEM teacher leader study showed that STEM teacher leaders are complex, flexible individuals who navigate expectations and standards to meet students' needs, which also matches the findings of (El Nagdi et al., 2018).

Summary of Four Themes

This section summarizes the four themes that emerged in this qualitative study. The purpose of the study was to investigate the practices of 10 elementary STEM teacher leaders through semi-structured interviews. Study findings and themes reflect the experiences and practices of STEM teacher leaders. Following data analysis, four themes surfaced from participant interviews, as shown in Table 8.

Table 8

Themes

Theme	Description
1. STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning.	Participants' experiences regarding how they became connected with STEM, the importance of developing an affinity with students, and what their affinity was with STEM
2. STEM teacher leaders use integrated STEM pedagogies.	Classroom experiences of teacher leaders as they teach STEM through inquiry, creativity, hands-on experiences, collaboration, real-world interest, and integration
3. STEM teachers function as school leaders by modeling innovation through STEM.	How STEM teacher leaders function within their schools through their roles leading professional development and advocating for students, and how they used data
4. STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches.	Among the challenges facing STEM teachers are time, resources, administrative support, and lack of professional development

Theme 1: STEM Teacher Leaders Exhibit an Affinity to STEM-Related Subjects, Experiences, or Important Figures in Their Lives Who Exemplified STEM Teaching and Learning

Participants discussed having personal affinities with teachers, family, or subject matter that inspired their interest in STEM topics. My findings suggest that this relationship factor created a kinship that led many participants to teach in a way that connected the students to STEM topics. Participants with strong feelings about STEM developed positive affinities with their students and families.

All teachers have a spark that connects them to become a teacher. My findings suggest that the difference with STEM teacher leaders is that they had a spark or affinity develop with a subject, person, or activity that centered around the STEM subjects. This makes their spark unique. Many participants explained that taking time to connect with students helps build affinities, with students then more likely to feel safe and participate in class as supported by (Cooper & Heaverlo, 2013). My findings suggest that what makes STEM teacher leaders stand out is their affinity revolves around a STEM subject. Chad asserted that taking the time to learn about students' interests provides information for teachers' later use. Winnie revealed that "bringing students on board" means building a connection, openly explaining the "why" behind class activities. My findings concluded that students want to be included in the decision-making for STEM projects; if they understand the purpose of the project, they will put more effort into their tasks. Participants provided multiple examples of building trust so that students recognize their ability to try something new and learn together. Many teachers build trust, but STEM teacher leaders are unique because they use the key pedagogies of STEM, like collaboration and hands-on learning to create opportunities to develop trust. This trust-building creates a partnership in which the students look to the teacher for guidance, giving STEM students some freedom to take ownership of their learning, as supported by (Wilkerson & Haden, 2014).

Theme 2: STEM Teacher Leaders Use Integrated STEM Pedagogies

My findings suggest the participants' fundamentals of how they taught with STEM: using inquiry, hands-on learning, collaboration, real-world problems, creativity, and reflection, as reinforced by (Cooper & Heaverlo, 2013; Lynch, 2017; Zimmerman, 2018). The study's themes were evident in classroom examples and discussions of STEM's purpose and challenges. My findings suggest that inquiry sparked the questions and investigations in their class, as supported by (Kelley & Knowles, 2016). Hands-on learning allowed for high engagement and connection with the lessons, as reinforced by (Lynch, 2017). My findings explained that collaboration allowed students to practice their soft skills and work in teams, as supported by (Sahin et al., 2014). Real-world problems make the lessons fresh and of high interest, as reinforced by (Shernoff et al., 2017). This study's findings revealed that creativity unleashed students' commitment to the task and ownership of their learning, as supported by (Ramirez, 2013). Finally, reflection gave students a chance to consider what they were learning and how to continually improve their efforts, as reinforced by (Jolly, 2014).

Additionally, participants discussed how they taught STEM. Teacher leaders described integrating STEM subjects into the standard curriculum. My findings suggest that this is unique to STEM teachers because they are integrating two or more subjects together. One challenge was inconsistent administrator support, which affected teachers' abilities to get supplies or even to use STEM in the classroom. Participants also discussed the "mess factor" that came with STEM supplies and projects, as supported by (Margot & Kettler, 2019).

The most powerful stories pertained to how STEM bridges the learning gap for Exceptional Children and AIG students, as reinforced by (Margot & Kettler, 2019). My findings suggest that STEM created equal opportunities for EC learners because all students have something to contribute. Shelby remained strategic with her student groups. She stated,

> I'm going to let them be a leader in an area that they might be stronger in. . . . Giving them the opportunity to lead in something that they're good at builds that confidence and sets them up to be able to take those risks later.

Overcoming STEM teaching challenges provided opportunities for students of any ability level to receive scaffolding support and make progress, as supported by (Krishnamurthi et al., 2013).

Theme 3: STEM Teachers Function as School Leaders by Modeling Innovation Through STEM

Participants described the tasks of STEM teacher leaders through the lens of the TLMS. My findings suggest that each TLMS theme emerged from participant interviews. Although many of the teacher leaders had limited preservice STEM experience, they showed perseverance in seeking out professional development opportunities. Professional development prospects arose from grants, local university programs, and social media interactions.

Material and resource acquisition posed challenges for teachers. Participants described how they have advocated for their students, subjects, and political policies to explain needs and negotiate support. My findings suggest that STEM teacher leaders conduct research for ongoing awareness of emerging best practices. The participants detailed how they collected, used, and reflected on data to support student learning. An area of growth emerged through the community stakeholder theme. However, although participants acknowledged the importance of community leaders supporting the schools, they shared few experiences. Overall, the 10 STEM teacher leaders created a rich narrative of how their leadership supported student STEM learning within their schools.

Theme 4: STEM Teacher Leaders Face Challenges and Barriers That Limit Their Implementation of STEM Approaches

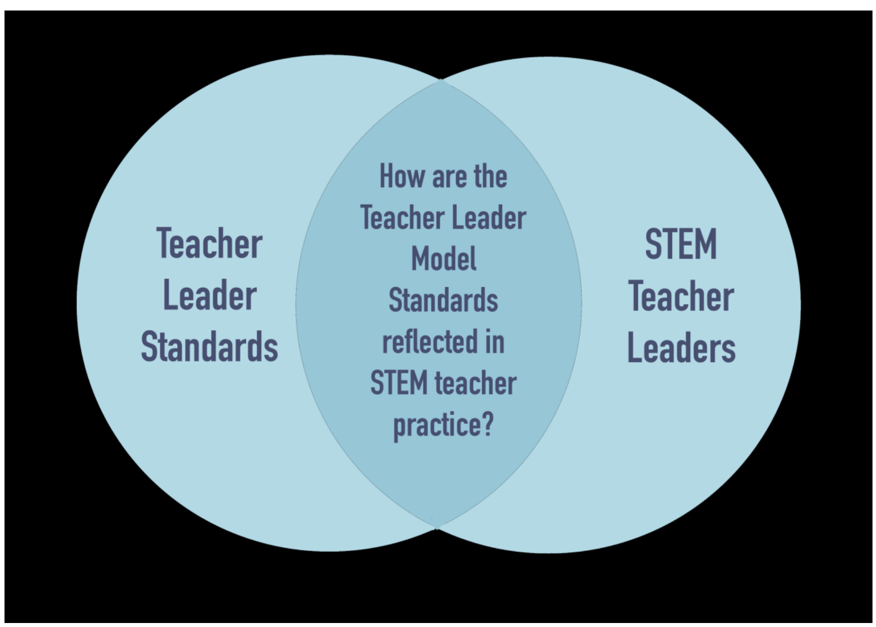
Participants candidly described the challenges that kept them from teaching with STEM, including testing stress, time, lack of administrative support, the "mess factor," lack of resources, and professional development, as supported by (Guzey, Moore, & Harwell, 2016; Guzey, Moore, Harwell, & Moreno, 2016; Stains et al., 2018). Testing stress revolved around how to weave STEM into the curriculum with all the tested standards taking precedent, as reinforced by (Margot & Ketter, 2019). My findings suggest that testing also connected to time, with STEM frequently cut from lessons due to time constraints or an alternate administrative focus. Participants described administrative support as something they needed help navigating, as they learned how best to communicate STEM needs, as supported by (Slavit et al., 2016). My findings suggest that there was a consensus about STEM's messiness, which could keep peers and administration from supporting their efforts, as reinforced by (Margot & Kettler, 2019). Participants described the need for resources and the difficulty in obtaining them, including project supplies and STEM professional development. Minerva explained that her administration allocated less time in the master school schedule for teaching science, contributing to the likelihood of teachers using STEM. My findings suggest from participants' rich descriptions, it is clear that administrative support affects STEM's welcomed or prohibited presence in the classroom.

Conceptual Framework Discussion

This section presents the study's framework and its application to the research, as illustrated with a Venn diagram (see Figure 3). One circle represents the Teacher Leader Model Standards (TLMS; Teacher Leadership Exploratory Consortium [TLEC], 2011), and one represents the practices and experiences of STEM teacher leaders. The intersection of the circles shows how STEM teacher leaders' work reflects the standards and best practices of the TLMS.

Figure 3

Conceptual Framework of STEM Teacher Leaders



One half of the figure reflects on the TLMS and explains how each strand is a characteristic of a teacher leader. The second half of the Venn diagram contains the details of the rich descriptive data from the qualitative STEM teacher leader interviews. The middle of the Venn diagram details STEM teacher leaders and how they reflect the TLMS in their STEM practice. Evidence of their STEM practices and leadership details are found in the four themes: STEM teacher leaders exhibit an affinity to STEM related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning, STEM teacher leaders use integrated STEM pedagogies, STEM teachers function as school leaders by modeling innovation through STEM, and STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches. These themes respond to my research questions, as detailed in the research question section.

Research Questions, Findings, and Themes

These were the STEM teacher leadership research questions:

What are the experiences and practices of STEM Teacher Leaders?

Two focus questions further define the study:

- How are the practices of STEM teacher leaders reflected in the Teacher Leader Model Standards?

How do STEM teacher leaders instructionally enact the pedagogical practices of creativity, collaboration, inquiry through real world problem-solving, and reflection in classrooms and schools? What are the experiences and practices of STEM Teacher Leaders?

- How are the practices of STEM teacher leaders reflected in the Teacher Leader Model Standards?
- How do STEM teacher leaders instructionally enact the pedagogical practices of creativity, collaboration, inquiry through real world problem-solving, and reflection in classrooms and schools?

RQ1: How are the Practices of STEM Teacher Leaders Reflected in the Teacher Leader Model Standards?

The STEM teacher leader participants showcased the standards of the TLMS (TLEC, 2011) as evidenced by the qualitative data collected in their interviews. My findings suggest that the four themes were revealed in the data crafted from lively descriptions and examples of a STEM teacher leader through the TLMS. Research Question 1 addressed each of the TLMS with thematic evidence from STEM teacher leaders.

TLMS Standard I) Fostering a Collaborative Culture to Support Educator Development and Student Learning

Participants described their school collaboration as a partnership, as evidenced in Theme 1, "STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning" with developing connections with people and STEM subjects, as supported by (Nickerson et al., 2017). My findings suggest that STEM teacher leaders used CASA, as discussed in Chapter IV, getting together to focus on students' standards-based mastery progress. CASA meetings are a time for teachers to collaboratively reflect on assessments, brainstorm interventions, and make adjustments in remediation plans for students, as described in Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM” as reinforced by (Nickerson et al., 2018). Weekly CASA meetings are by grade level and include administration, curriculum leaders, and teachers, which demonstrate Theme 3. My findings suggest that beyond active participation in CASA, participants shared that collaborative support encouraged a classroom mindset shift to use best practices for student improvements, as evidenced in Theme 2, “STEM teacher leaders use integrated STEM pedagogies” through classroom experiences as supported by (Cooper & Heaverlo, 2013).

TLMS Standard II) Accessing and Using Research to Improve Educator Development and Student Learning

The participants described creative ways in which they completed research and professional development, as detailed in Theme 3. My findings suggest that participants shared accessing STEM professional development through administrator requests, grants, social media, and additional college degrees in themes 2 and 3, as supported by (Hunzicker, 2017). There was a consensus of the critical need to access and use current research to improve teachers’ professional skills and support student learning with details in Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM.”

An area of research that STEM teacher leaders were puzzled with was the Next Generation Science Standards (NGSS). North Carolina was a forerunner in creating the standards; yet has refused to adopt them. My findings suggest that teachers felt that the NGSS blends STEM pedagogies with curriculum needs, as evidenced in Theme 2, “STEM teacher leaders use integrated STEM pedagogies.” Several teachers described that they had spent time researching how to blend the STEM-friendly NGSS with the NC standards, as evidenced in Theme 3, in order to meet state expectations, as well as, include STEM skills.

TLMS Standard III) Promoting Professional Learning for Continuous Improvement

Participants who attended administrator-mandated STEM professional development were pleasantly surprised to be inspired by the workshops, as reviewed in Theme 2, “STEM teacher leaders use integrated STEM pedagogies.” For many of these teacher leaders, assigned development was the first time a STEM experience garnered their interest. Several participants received university grants for STEM training, often focused on project and inquiry-based learning, as described in Theme 2, as reinforced by (Nickerson et al., 2018). Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM” details one of the best ways the teachers had found to participate in STEM professional development was through social media. Rory described using Twitter to connect with fellow science teachers and individuals who teach with STEM to share ideas; Barbara followed teachers’ Instagram accounts to keep current on STEM. In Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM,” several participants remarked that continuing their education with graduate degrees or add-on licenses also inspired their professional growth.

My findings suggest that in Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM,” the 10 participants described their roles as instructional leaders, as they facilitated professional development within their schools. Some led informal peer support, whereas others presented school-wide training. The roles of digital learning coach and personalized learning ambassador required teacher leaders to share best practices and innovations in digital or personalized learning, as evidenced in Theme 3. Themes 1 and 3 detail how in these roles, teachers work as instructional leaders, affecting how peers collaborate and challenge their students using the best digital practices.

TLMS Standard IV) Facilitating Improvements in Instruction and Student Learning

Participants provided classroom examples of STEM strategies they have shared with other educators. In Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM,” participants explained that their school leadership roles focused on instructional improvements for all students. They discussed their leadership roles in supporting MTSS or SIT, as these committees make decisions that impact the entire school. My findings suggest that several participants embraced digital learning coach and personalized learning ambassador roles to collaboratively affect instructional improvements in Theme 3. These digital coaching roles expose teachers to current professional development, providing information they bring back to their schools for implementation. Therefore, teacher leaders in these roles are poised to enhance student learning goals through collaboration with peers, as evident in Theme 3.

In Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM” several participants supported fellow teachers in their schools informally. One example of such support included promoting STEM bins and explaining how to incorporate the bins into their classrooms. Participants variously discussed teaching their colleagues how to use Google Classroom, implement new digital tools, and improve parent communication with digital platforms. The teacher leaders' stories showed how schools use data, offer professional development, and create collaborative learning with peers to facilitate instructional best practices in Theme 3.

TLMS Standard V) Promoting the Use of Assessments and Data for School and District Improvement Standard

My findings suggest that STEM teacher leaders used data to drive instruction through assessments based on curriculum standards, then created a remediation plan specific to student needs, as evident in Theme 3, "STEM teachers function as school leaders by modeling innovation through STEM." After completing remediation, students undergo testing again to check for improved understanding. The continuous learning-testing cycle ensures that teachers support students based on data, with scaffolding provided to reach their goals, as reinforced by (Wenner, 2017). Theme 3 explains this data-driven instruction which offers participants a clear view of which students need help and whom to accelerate. Participants were very knowledgeable as they described navigating the data-based decision process.

Theme 3, "STEM teachers function as school leaders by modeling innovation through STEM," details participants' use of data to drive instruction is a school-wide process. My findings suggest that STEM teacher leaders take ownership in coding and analyzing their own assessment data. They make decisions on the next direction to move their class throughout the curriculum. This process ensures that students are offered support or acceleration where needed through the use of data, as explained in Theme 3.

TLMS Standard VI) Improving Outreach and Collaboration with Families and Community

In Theme 1, “STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning” participants shared rich experiences of connecting students and families with their classrooms. My findings suggest that the importance of family affinities with specific stories of family class volunteers and parent conferences focused on supporting students’ well-being and sharing academic growth connections with families. Participants described creating family connections by communicating with families about how they can support classroom learning at home, as evident in Themes 1 and 2. Theme 1, “STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning,” describes how Rory built affinities by inviting families to volunteer. She recalled a family visit that involved experimenting with a wood-burning tool used for a heat-transfer marshmallow experiment. Unfortunately, the experiment turned into an accidental warping of the Formica table. Rory turned this accident into a new phenomenon, asking students to explain why the heat-transfer burn happened. Her willingness to create a learning opportunity from a mistake showed that students and STEM teachers learn from each other. My findings suggest that building a relationship with students and families made teaching easier because of shared trust, as evident in Theme 1.

The Title I school participants had many opportunities to welcome families for engaging activities that connected parents and learning as described in Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM,” as supported by (Wenner, 2017). However, Theme 3 detailed there was a deficit in community connections. Limited data emerged regarding community businesses, faith-based support, or local leaders supporting schools, as noted in Theme 4. For STEM teacher leaders, these were widely untapped resources for student, family, and school support.

TLMS Standard VII) Advocating for Student Learning and the Profession—Teacher Leaders are Necessary for School Growth

My findings suggest that teaching entails nurturing the whole child, as reinforced by (Klein et al., 2018) and advocating for student needs. In Theme 1, "STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning." Minerva found that the process of building student affinities can sometimes uncover needs or inequalities with which students require assistance. She said,

> I think teachers have to realize that the affinities that we have with all these little people, we're almost that only person anymore who is going to get them resources, get them help, identify a problem. Forget the teaching, forget the science, forget the reading, math, and all that. . . . They've got to be able to survive first, and I think that is heartbreaking at this point.

Participants discussed being advocates for students to procure the necessary resources, as evident in Theme 3, "STEM teachers function as school leaders by modeling innovation through STEM." Specifically, teachers helped students locate support for SEL, EC, and personal needs. STEM teacher leaders spoke out for their teacher peers by requesting professional development and resources. In Theme 3, several participants also mentioned political advocacy, as they identified concerns and communicated them to parents, community, and peers.

Summary

The four research themes provided an animated view of the many ways that STEM teacher leaders reflect the TLMS. Each TLMS brings a leadership trait that is needed for STEM teacher leaders to continue STEM and increase student learning. The thematic evidence supports the current practices of STEM teacher leaders through TLMS.

RQ2: How Do STEM Teacher Leaders Instructionally Enact the Pedagogical Practices of Creativity, Inquiry Through Real-World Problem-Solving, and Reflection in Classrooms and Schools?

My findings reflect that STEM teacher leaders engage in the pedagogical practices of creativity, collaboration, inquiry through real-world problem solving, and reflection as paramount in their current STEM classrooms. These are reflected as subheading with data collected from the thematic findings. Integrating these best practices provided students with an engaging STEM challenge, as supported by (Cooper & Heaverlo, 2013). Participants found each of these practices powerful and instrumental in teaching students with STEM.

Barbara described STEM teaching as a method that blended subjects to help students understand concepts through lessons that engaged multiple pedagogical STEM practices, as evident in Theme 2. One example given was a hurricane project. Students worked collaboratively to creatively determine how to construct a building to withstand hurricane-strength winds. The use of inquiry enabled the students to test their hypotheses. This project presented a real-world challenge, as students were familiar with living in hurricane zones, thus making the challenge relatable and current. The final pedagogical component of STEM learning is reflection. My findings suggest that “reflection” is what students learned, what they could do better, and what they want to learn more about. Reflection was an area of growth for the participants, who were eager to learn about new strategies.

Creativity

My findings suggest that creativity in STEM is the “glue” that connected students to learning, as found in Theme 2. Creativity allowed students the freedom to dream, experiment, and have ownership in their work. My findings suggest that the creativity in STEM creates high interest and purpose and inspires adaptations to construct better solutions, as evident in Theme 2. Unleashing creativity allowed students to become highly engaged in the STEM process. As noted in the data collected from Theme 4, “STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches,” participants acknowledged that creativity made them nervous because they lacked professional development and confidence to incorporate creativity into STEM lessons. Participants agreed that STEM creativity was necessary; however, they worried about using it correctly and how to shift from creativity to active problem-solving solutions; as further explained in Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM.”

Collaboration

My findings suggest that collaboration is a needed component of STEM that promotes students working together to complete challenges, as reinforced by (Cooper & Heaverlo, 2013). Theme 2, “STEM teacher leaders use integrated STEM pedagogies” explained how each participant promoted the use of collaboration, and many relied on class expectations with specific parameters for students to safely share ideas, commit to plans, and complete a final project. As reflected in the data of Theme 1, “STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning.” STEM teacher leaders developed positive connections in order for students to feel safe in order to share ideas and collaborate. Collaboration pairings promote productive peer discussions and cooperation, as supported by (Nickerson et al., 2018). According to Theme 2, 10 teacher-learners confirmed that collaboration allowed students to improve their communication skills by learning how to use their voice in explaining how they agreed or disagreed with peers.

Inquiry Through Real-World Problem-Solving

My findings suggest that STEM is most meaningful for students when it connects to the world around them, as reinforced by (Zimmerman, 2018). As noted in Theme 1, “STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning,” participants found that student engagement increased when students could make a personal connection with a STEM lesson. However, my findings suggest that teacher leaders cited time, stress, limited professional development, and lack of resources as reasons for the administration’s removal of real-world learning from their classes; as explained in Theme 4, “STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches.”

An example of a real-world, inquiry-based, hands-on project is the decimal Christmas shopping problem, as detailed in Theme 2. In this challenge, students use real store flyers to complete holiday shopping. The catch is that the students have received no instruction on adding or subtracting decimals, requiring them to figure it out as they work through the task. Barbara described how the math challenges arose naturally in the project, allowing her to provide mini-lessons to scaffold support for the students while allowing the children to experiment and discover on their own. Details in Theme 4, “STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches,” describes how real-world learning was an area that participants described with excitement; however, it was also the approach most often cut due to time constraints.

Reflection

Participants said the importance of the reflection process was to provide students with a closure activity, as reinforced by (Jolly, 2014). My findings suggest that reflection allows students to recognize what they learned, what improvement suggestions they have, and what questions remain, as supported by (Margot & Kettler, 2019). Several participants reported using journaling or interactive notebooks for reflection; some used reflection as an informal check-in on students’ understanding of the topic. As explained in Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM,” there was a consensus among participants regarding the difficulty in reserving time for reflection. Participants acknowledged that they needed professional development and suggestions on best practices necessary to improve their classroom reflection skills.

My findings suggest that reflection was critical; the process of education facilitates improvement, allowing students to continue to explore and grow.

Implications

My findings suggest that STEM teacher leaders deliver the necessary, high-quality STEM education students anticipate and need, as reinforced by (El Nagdi et al., 2018; Guzey, Moore, & Harwell, 2016). Therefore, district and school leaders must communicate clear expectations for how and when STEM education will occur. Because researchers and education professionals agree that STEM-related occupations are the future of the job market, as supported by (Schwantes, 2017), it is essential to best prepare, support, and encourage teachers to advance student growth.

A synthesis of the findings from this study led to recommendations for awareness, professional development, and updates to visions or expectations. Implications and recommendations apply to current STEM teacher leaders, policymakers and administrative leaders, researchers, and universities that prepare STEM teachers. The implications vary based on the role of each stakeholder in supporting STEM teacher leaders in rural schools. Preparing and helping teacher leaders to teach future STEM entrepreneurs, problem-solvers, and community leaders are critical to advocate for continued growth and support.

STEM Teacher Leaders

STEM teacher leaders must connect. Committing to creating, fostering, and sustaining affinities is the greatest approach to move forward with STEM. Having a passion for STEM topics motivates individuals to teach the subjects better than they were taught. STEM teachers must embrace and grow that passion to create affinities with each student, sharing their interest and excitement in STEM. STEM teacher leaders must clearly communicate their goals and needs so that supporters can reinforce the mission.

As indicated in Theme 1, “STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning,” STEM teacher leaders should regularly collaborate with peers, sharing their lessons for observations, participating in staff meetings, and remaining open to feedback. Teachers will be more willing to learn when it is not mandatory and their peers celebrate their success. Demonstrating one’s commitment through servant leadership helps sharing and growth to become part of the school culture, as evident in Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM.” Other recommendations are to encourage questions and collaboration, network face to face and on social media to share ideas, and be approachable. STEM teachers should congratulate and support colleagues who are willing to try STEM ideas, as indicated in Theme 1, “STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning.” Having a STEM mentor is an asset.

Teachers of color are noticeably absent from the STEM teacher leadership role. Encouraging and fostering mentorships will provide coaching and support for teachers of color, as evident in Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM.” Students respond best to teachers who look like them; not supporting STEM teacher leaders of all races and ethnicities limits students’ access to and interest in STEM. Current and aspiring STEM teachers should look within the community to find educators, as mentioned in Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM” with the desired skills or leadership traits, making contact to engage regular check-ins and shadowing opportunities.

The findings from my study indicated that STEM teacher leaders may not feel that they are school leaders. I encourage you to take ownership of your leadership by speaking out and asking school administration how you can help. You have so much to offer and the assumption could be that you are not interested or lack the skills. Become a self-advocate and offer to be the person to rise up to leadership positions. Often, teachers do not feel entitled to ask for what they need. However, by not asking, they give the perception of lacking nothing. As implied in Theme 2, “STEM teacher leaders use integrated STEM pedagogies,” teachers need to expand their capacities by selecting an area of growth and pursuing professional development. Through networking, teachers can ask others to identify the most rewarding professional development opportunities. Teachers must always be willing to advocate for their STEM students and seek resources, as evident in Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM.” Theme 2, “STEM teacher leaders use integrated STEM pedagogies” suggests writing grants, connecting with local organizations or universities, and using social media are ways to locate the tools these teachers need. There must be clear communication with school administration regarding the teacher’s professional growth and materials procurement needs. This was evident in the discussion of Theme 4, "STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches."

Overwhelmingly, community stakeholders are untapped resources, with many potential partnerships possible by making connections. Local leaders, businesses, or faith-based organizations are stakeholders who could support teachers' learning goals. Community stakeholders can serve as mentors, class support, advocates, and resource-providers. Welcoming community members into the classroom can become a mutually beneficial partnership, as discussed in Theme 3, "STEM teachers function as school leaders by modeling innovation through STEM."

Policymakers and Administration Leaders

Policy makers and administration leaders make decisions based on the needs of students, teachers, and schools. Governments establish curriculum expectations and testing plans. Policymaker leaders must take steps to make STEM education available to all students. Administrators can encourage STEM growth through professional development, support, communication, and stakeholder connections, as evident in Themes 1, 3, and 4.

These findings show that STEM leadership starts with Theme 1, "STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning." It is important to build positive connections with teachers who are strong, determined, and focused on empowering their students. Investing in connections with teachers is a worthwhile effort; taking time to visit classrooms, share words of encouragement, and solicit teachers' opinions grows educators' capacity to become school leaders, as evident in Theme 1, "STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning." School administrators should take the time to ask teachers what they need to grow professionally. Teachers feel empowered when they have administrator support, as implied in Theme 4, "STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches." My study findings indicate that oftentimes teachers do not feel like leaders in the school. Leadership has a responsibility to encourage leadership growth, set up opportunities for mentorship and experiences so that teachers can experiment with locating their leadership voice.

Teachers need ideas on how to access materials and resources to be effective using STEM. Allotting monies and encouraging grants will help teachers secure the necessary tools to instruct with STEM, as mentioned in Theme 3, "STEM teachers function as school leaders by modeling innovation through STEM." Teaching STEM requires educators to cede control and do something different; thus, administrators must provide teachers with safe spaces and encouragement, as described in Theme 1, "STEM teacher leaders exhibit an affinity to STEM-related subjects, experiences, or important figures in their lives who exemplified STEM teaching and learning." In small, rural communities, administrators' words and actions are known; thus, actions should communicate administrators' visions for students, teachers, and families.

Although North Carolina helped create the NGSS that focuses on inquiry-based learning, the state has not adopted the current STEM-based standards. As discussed in

Theme 2, “STEM teacher leaders use integrated STEM pedagogies” adopting NGSS would help shift the educational focus to teaching science through a STEM lens. North Carolina has a significant opportunity to include NGSS curriculum standards for students to compete in future job markets, bringing impactful jobs and industries to communities.

Political and administrative leaders have an imperative to talk to educators before making policy decisions that impact current teachers. Taking the time to speak with current practitioners will inform educators how progressive legislation and supportive curriculum adjustments could positively affect students, teachers, and communities.

As indicated by past research and the current study’s findings, STEM is the future of students and communities, preparing youth for jobs to come (Education Commission of the States, 2019). However, STEM teacher leaders of color are noticeably absent, thus indicating the need for mentorships for minority teachers to connect with STEM (Moss, 2016). Policymakers have a responsibility to students to direct resources, time, and development, creating a culture of legislation and political leaders who support educators. By increasing legislative support of educators, teachers can challenge all students to prepare themselves for later STEM leadership roles.

STEM teacher leaders are often unsure about administrator expectations, as evident in Theme 4, “STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches.” They wonder if STEM is allowed, how much they can do, or what is a reasonable time allowance for lessons. Teacher leaders also believe that if they teach with STEM, their students will be prepared to analyze STEM subjects in person or on standardized tests. However, teachers are often nervous about broaching the subject with school leaders in fear that drawing attention to STEM will lead to its removal, as explained in Theme 4, “STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches.” Before making decisions, administrators should research STEM and the direct correlation to test scores, and then help staff navigate school and district expectations. Without administrative understanding and support, STEM lessons may be undervalued or nonexistent.

Absent from the STEM teacher leadership role are teachers of color (Moss, 2016). Access to STEM must be equitable for all teachers and students. Due to the limited participation of STEM teachers of color, entire student populations cannot receive instruction from a teacher who looks like them. Administrators should, therefore, conduct mindful recruitment, supporting teachers of all races and ethnicities.

Researchers

This qualitative study generated implications for future research beyond the scope of this research. The focus of this study was STEM teacher leader pedagogies and leadership roles within rural elementary schools. Through Theme 3, “STEM teachers function as school leaders by modeling innovation through STEM” topics such as community stakeholders and STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches emerged as themes in need of further exploration. More research is needed to identify each challenge and offer solutions to support more STEM teacher leaders.

Throughout Theme 4, “STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches,” participants in the study were facing multiple challenges to STEM education, along with providing a few suggestions. Additional areas of study include analyzing challenges, such as curriculum concerns, professional development, and testing. Further research would entail identifying possible solutions for these challenges. Teacher leaders need practical, timely suggestions to make STEM more accessible to all students, as evident in Theme 4.

Creating a better understanding of STEM students' interests and challenges would help prepare STEM teacher leaders to meet learners' needs. STEM students are adapting as STEM evolves, yet this information would provide a blueprint for designing STEM curriculum and project-based learning to engage students. Teachers will be better equipped to anticipate needs if they understand what interests their students, as evident in Themes 1 and 2. Research is needed to prepare STEM teachers to become leaders. Few participants had learned about STEM in college. Understanding the pathways that prepared current educators, both veteran and beginning teachers, would help identify pitfalls and missed opportunities. Colleges and universities need a better understanding of what is missing from their curriculum, with a specific focus on how to prepare pre service STEM teachers, as evident in Theme 3, "STEM teachers function as school leaders by modeling innovation through STEM." Additionally, understanding what STEM teachers need to transition into school leaders would help prepare them. This research also showed a lack of diversity in STEM teacher leaders. More inclusive recruitment and support of diverse STEM teacher leaders would benefit all students.

There is an untapped capacity for developing community stakeholder support and STEM partnerships, detailed in Theme 3, "STEM teachers function as school leaders by modeling innovation through STEM." Stakeholder connections will deepen the meaning for STEM students. STEM teacher leaders need to learn how to create positive partnerships, how to foster their growth, and how both parties can benefit from one another's support. This topic was absent from the research and would be important information for the whole community to reinforce STEM growth.

Universities That Prepare STEM Teachers

STEM teacher leaders should have a strong background in the following STEM pedagogies: Inquiry, Hands-on, Real World, Creativity, Collaboration, and Reflection, as detailed in Theme 2, "STEM teacher leaders use integrated STEM pedagogies." Many of this study's participants had developed their knowledge from a combination of coursework and teaching experience. University and college leaders must advocate for supporting pedagogies that facilitate STEM education. These pedagogies are critical for developing students into real-world problem-solvers.

STEM teacher leaders need a strong background in integration to navigate expectations in public schools, as evident by Theme 2, "STEM teacher leaders use integrated STEM pedagogies." Engaging in the powers of integration will allow teachers more flexibility in embedding STEM into their lessons. Integration will also reduce the stress of older systems to more easily incorporate STEM into the curriculum.

Participants were unsure of how best to add STEAM elements and reflection strategies. Professional development is needed for teachers to understand methods for offering engaging STEAM and solid reflection skills, as indicated in Theme 3, "STEM teachers function as school leaders by modeling innovation through STEM." Through semi-structured interviews, the 10 participants shared feelings they felt the most uncomfortable and unprepared in these two areas, both of which would profoundly enhance STEM efforts.

STEM teacher leaders will need help locating resources and a peer support system. They require coaching to learn how to communicate needs to their administration team, as evident in Theme 4, “STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches.” STEM teacher leaders require strategies to identify how and when to embed STEM into their curriculum as evident in Theme 2, “STEM teacher leaders use integrated STEM pedagogies.” STEM teacher leaders also need support in navigating testing stress versus implementing STEM projects, as mentioned in Theme 4, “STEM teacher leaders face challenges and barriers that limit their implementation of STEM approaches.” Preparing teachers for the reality of STEM in school will help formulate solutions and later success.

An area widely untapped is family and community support. Preservice teachers need to understand how to connect with parents, collaborating with them under a shared vision for their students. Teachers should know how to communicate, share volunteer options, and foster common goals. Connecting teachers and community stakeholders will increase mentorship opportunities for teachers and students, resources, and positive advocacy toward the teacher and STEM.

Final Reflections

Affinities and Connections

During this research, one significant finding emerged surrounding positive connections and developing affinities with people and subjects. It is the affinities and connections people have that allow STEM to flourish or falter. One connection the teacher has is with the subject matter (e.g., exhilaration, fear, annoyance, or something in between). Next is the connection STEM teacher leaders have with peers and building leaders, affecting how willing the teacher is to advocate and use STEM. Critically, there is the connection the teacher has established with students, impacting the students' willingness to engage with STEM. Affinities with parents, community stakeholders, and outside media outlets either contribute to or detract from the use of STEM in classrooms. STEM teacher leaders should know that they have support, and their school is a safe space to implement STEM pedagogies.

Let the Light Shine

Throughout this study, I uncovered insight into STEM teachers who did not see themselves as school leaders. This finding was equally surprising and frustrating, especially after seeing the many ways STEM teachers were active leaders within the school, coaching, leading professional development, heading committees, and mentoring. What does it mean when participants remark that they are not a teacher leader? Through participant data I would suggest that it means that they are not confident in their abilities, lack mentors, or are unsure of how they meet the TLMS criteria to be a teacher leader. School leadership needs to provide ongoing coaching to STEM teacher leaders on how they can use current leadership positions and opportunities to display their use of STEM and encourage colleagues to do the same. If teachers believe themselves to be respected school leaders, they will feel empowered to make a tremendous positive impact on peer teachers and students.

Shelby's principal asked if she believed she *really* teaches with STEM, making her second-guess if she was a STEM teacher leader. The inquiry caused reflection, and she responded, "Uh, no, actually I don't. Not as nearly as much as I would want." Shelby described the rapidly moving pacing guide as a hazard to STEM:

> More like support from the administration saying, "I want you to do this. This is important. You need to do this." I think their emphasis on it has a lot of impact on whether the teachers are driving to do it or not. . . . I know there's a lot riding on test scores at the end of the year . . . maybe even the IC [instructional coach] coming in and co-teaching a STEM activity—those sort of things would definitely push teachers to be more open to it and try it out. . . . If my principal is emphasizing it, then my whole team might work with me on creating it versus me doing it on my own.

Along with other participants, Shelby was searching for the administrative support necessary for her to feel empowered to lead with STEM in her classroom. From participants' rich descriptions, it is clear that STEM can be a welcome or disallowed approach in the classroom based on administrator support. Participants' responses indicated that some STEM occurs behind closed classroom doors. It is a real concern that teachers are unsure of how much STEM they can do and when.

Purposefully Recruiting Diverse Teachers

While recruiting participants for this STEM teacher leadership research, I specifically targeted teachers who represented the diversity of the rural setting. It was challenging to locate a STEM teacher leader of color. I was very confident to defy the recent research which portrayed a lack of diverse STEM teachers because in my professional role I have observed them, given positive feedback to, and developed relationships with several teachers of color in STEM. Despite several recommendations for participants of color, my repeated attempts of recruitment, and my personal connections the result remained that each possible participant declined to participate. Among the final sample, the 10 participants were White, and all but one were female.

Some of the barriers preventing women from academic success are outdated stereotypes and feelings of insufficiency, as reinforced by (Modi et al., 2012). McGee (2013) reported that minority students involved in Advanced Placement courses are as likely as White students to pursue STEM studies. Statistics show that over half of African American and Native American STEM students drop out or change majors, as supported by (White et al., 2006). One of the reasons for dropout is the lack of support systems for minority students, as reinforced by (Wassell et al., 2015; White et al., 2006). If no peer or family support groups are available, minority students often turn to helping their family financially, which leads to dropping out, as reinforced by White et al. (2006). Multiple STEM minority retention programs include mentoring, stipends, research opportunities, and summer leadership experiences (Schultz et al., 2011). Despite these intervention efforts, there is little consensus regarding the effectiveness of services for keeping minority students connected with STEM academia (Schultz et al., 2011). Statistically, there is evidence that minority students are not making the STEM journey from primary school to STEM careers. As noted by Hossain and Robinson (2012),

> The US should prepare all students, especially minorities and girls, who are underrepresented in these fields, to become more motivated and proficient in STEM subjects. To support this goal, partnership and collaboration of private and philanthropic groups with local and state government are essential. To motivate a greater number of students and the non-STEM workforce to join the STEM pipeline, a number of steps at various levels should be taken and monitored closely. (p. 448)

It would be a critical charge for STEM leaders to target minority participation, engagement, and commitment to STEM for later growth into STEM leaders.

One takeaway from this research is that STEM has limited reach for teachers of color. Despite the best efforts, I was unable to recruit diverse participants for this study. Schools need to be purposeful in recruiting teachers of color, locating mentors, and providing leadership opportunities. Extra efforts from universities will provide support for STEM teachers in their pursuits of STEM leadership. It is frustrating that STEM remains an exclusive group without the encouragement of all teachers.

Professional Development Plan

Throughout this study, participants discussed the difficulty of locating professional development and the areas in which they needed more support to teach STEM confidently. In response, I constructed a simple set of questions to pair with the evaluation professional development plan. In public schools in the region of study, administrators meet with teachers three times a year to discuss plan progress. Administrators could use these questions as teacher check-ins, with the responses enabling them to provide teacher support while building the affinities that support student growth. See Table 9.

Table 9

STEM Teacher Leader Professional Development Plan

Challenge	Question
Connections	• Tell me about how you are developing student connections. • Describe how you have improved parent connections. • How have you connected with community stakeholders?
Pedagogy	• Which teaching pedagogy has been the most successful for you recently? • Describe which teaching pedagogy you would like to learn more about.
Pitfalls	• What is an obstacle that keeps you from success in your classroom? • What are strategies to work around this obstacle?
Goals/vision	• After reflecting on these questions and your professional growth plan action items, describe what steps need to be taken to reach your goals.

Closing Thoughts

Completing this research has cemented my belief that STEM teacher leaders are a critical component of school leadership and student growth. Students receive opportunities to extend their problem-solving skills and become fully engaged in STEM subjects through innovation and teacher commitment to high-level pedagogies. STEM creates students who will become productive citizens and problem solvers who challenge the status quo.

As an educator who has spent 18 years supporting student growth and development, I am convinced that hiring, supporting, and cultivating teacher leadership are essential to building strong schools. Teacher leadership empowers educators to bring confident changes to their classrooms and schools to meet student needs. Currently, school goals are to supply students with skills that they need to be successful and create positive impacts in the community.

Recently, with the COVID-19 pandemic, individuals have turned to schools for answers. In my school community, teachers brainstormed together, thinking so far outside the box that they could construct meaningful solutions after receiving little professional development about multiple online learning platforms and social and emotional support for the whole child. There is a need for school leaders to ask questions, make mentor connections, and challenge teachers to think ahead to bring out their best. The pandemic might have created some of the worst of times; however, there is now much more evidence of how teachers have been inspired, met unique demands, and proven their worth. I believe that using professional development guiding questions would allow school leaders to promote reflection and challenge thinking, thus inspiring and cultivating new STEM teacher leaders and empowering their staff.

REFERENCES

Acevedo, S. (2018). *Author. Entrepreneur. Engineer. Rocket scientist.* https://www.loc.gov/item/lcwaN0026125/

Afterschool Alliance. (2013). *Partnerships with STEM-rich institutions.* Retrieved from http://files.eric.ed.gov/fulltext/ED546853.pdf

Appleton, K. (2013). How do beginning primary school teachers cope with science? Toward an understanding of science teaching practice. *Research in Science Education 33*(1), 1–25. https://doi.org/10.1023/A:1023666618800

Asunda, P. A., & Mativo, J. (2015/2016). Integrated STEM: A new primer for teaching technology education. *Technology and Engineering Teacher, 75*(4), 8–13. https://eric.ed.gov/?id=EJ1083032

Avendano, L., Renteria, J., Kwon, S., & Hamdan, K. (2019). Bringing equity to underserved communities through STEM education: Implications for leadership development. *Journal of Education Administration and History,* 51(1), 66–82. https://doi.org/10.1080/00220620.2018.1532397

Barshay, J. (2019). What 2018 International PISA rankings tell us about US Schools. *The Hechinger Report.* https://hechingerreport.org/what-2018-pisa-international-rankings-tell-us-about-u-s-schools/

Bequette, J. (2012). A place for art and design education in the STEM conversation. *Art Education, 65*(2), 40–47. https://doi.org/10.1080/00043125.2012.11519167

Berk, L. J., Muret-Wagstaff, S. L., Goyal, R., Joyal, J. A., Gordon, J. A., Faux, R., & Oriol, N. E. (2014). Inspiring careers in STEM and healthcare fields through medical simulation embedded in high school science education. *Advances in Physiology Education*, *38*(3), 201–215. https://doi.org/10.1152/advan.00143.2013

Bialik, M. (2015). *Who said girls are not good at STEM?* [Commentary]. CNBC. http://www.cnbc.com/2015/09/18/who-said-girls-arent-good-at-stem-commentary.html

Bowden, L. (1975). Effects of World War II in education in science. *Proceedings of the Royal Society of London, 342*(1631), 499–503. http://www.jstor.org/stable/78749

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics, 112*(1), 3–11. https://doi.org/10.1111/j.1949-8594.2011.00109.x

Brown, K. M. (2006). Leadership for social justice and equity: Evaluating a transformative framework and andragogy. *Educational Administration Quarterly, 42*(5), 700–745. https://doi.org/10.1177/0013161X06290650

Brubaker, D., & Coble, L. (2005). *The hidden leader: Leadership lessons on the potential within.* Corwin.

Bureau of Labor Statistics. (2019). *Occupational Outlook Handbook*. U.S. Department of Labor. https://www.bls.gov/ooh/.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher, 70*(1), 30–35. https://eric.ed.gov/?id=EJ898909

Casserly, M. (2013). *Mayim Bialik's 'Big Bang Theory' on girls, STEM careers and role models.* Retrieved from https://www.forbes.com/sites/meghancasserly/2013/03/15/mayim-bialiks-big-bang-theory-on-girls-stem-careers-and-role-models/#5b28ad20f531

Catone, K., Saunders, M., Perez, W., Harris, E., & Miller-Gootnick, R. (2018). *Agency into action: Teacher as leaders and advocates for public education, communities, and social justice.* Teacher Leadership & Advocacy. https://files.eric.ed.gov/fulltext/ED582092.pdf

Cavanagh, S., & Trotter, A. (2008, March 21). Where's the "T" in STEM?: Experts debate whether the practical applications of math and science are getting all the attention they deserve. *Education Week, 17*(30), 17–19. https://www.edweek.org/ew/articles/2008/03/27/30stemtech.h27.html

Cooper, R., & Heaverlo, C. (2013). Problem solving and creativity and design: What influence do they have on girls' interest in STEM subject areas? *American Journal of Engineering Education, 4*(1) 1–38. https://doi.org/10.19030/ajee.v4i1.7856

Cosenza, M. (2015). Defining teacher leadership: Affirming the teacher leader model. *Issues in Teacher Education, 24*(2), 79–99. https://files.eric.ed.gov/fulltext/EJ1090327.pdf

Creswell, J. W. (2015). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (5th ed.). Pearson.

Dahill-Brown, S., & Jochim, A. (2018). *The power of place in rural schools.* School Administrator. http://my.aasa.org/AASA/Resources/SAMag/2018/Oct18/Dahill-Brown_Jochim.aspx

Dailey, D., Bunn, G., & Cotabish, A. (2015). Answering the call to improve STEM education: A STEM teacher preparation program. *Journal of the National association of Alternative Certification, 10*(2), 3–16. https://files.eric.ed.gov/fulltext/EJ1083948.pdf

Davies, D., & Stammers, J. (1975). The effects of World War II on industrial science. *Proceedings of the Royal Society of London, 324*(1631), 505–518. https://doi.org/10.1098/rspa.1975.0041

DeChenne, S., Nugent, G., Kunz, G., Linlin, L., Berry, B., Craven, K., & Riggs, R. (2014). *Coaching in a science, technology, engineering, and math professional development experience: A case study.* The National Center for Research on Rural Education. http://r2ed.unl.edu/workingpapers/2014/2014_7_DeChenne_Nugent_Kunz_Luo_Berry_Craven_Riggs.pdf

Desilver, D. (2017, February 15). *U.S. students' academic achievement still lags that of their peers in many other countries.* Pew Research Center. http://www.pewresearch.org/fact-tank/2017/02/15/u-s-students-internationally-math-science/

Dierking, L. D., & Falk, J. H. (2016). 2020 vision: Envisioning a new generation of STEM learning research. *Cultural Studies of Science Education, 11,* 1–10. https://doi.org/10.1007/s11422-015-9713-5

Dugger, W. (2010, January 1). *Evolution of STEM in the United States.* http://www.iteea.org/Resources/PressRoom/AustraliaPaper.pdf

Education Commission of the States. (2019). *STEM demand.* http://vitalsigns.ecs.org/state/united-states/demand

Ejiwale, J. (2012). Facilitating teaching and learning across STEM fields. *Journal of STEM Education: Innovations and Research, 13*(3), 87–94. https://www.jstem.org/jstem/index.php/JSTEM/article/download/1711/1464

El Nagdi, M., Leammukda, F., & Roehrig, G. (2018). Developing identities of STEM teachers at emerging STEM schools. *International Journal of STEM Education, 5*(1), Article 36. https://doi.org/10.1186/s40594-018-0136-1

Elrod, S. (2010). Project Kaleidoscope 2.0: Leadership for twenty-first-century STEM education. *Liberal Education, 96*(4), 24–33. https://www.aacu.org/publications-research/periodicals/project-kaleidoscope-20-leadership-twenty-first-century-stem

Fayer, S., Lacey, A., & Watson, A. (2017, January). *STEM occupations: Past, present, and future.* U.S. Bureau of Labor Statistics, Spotlight on Statistics. https://www.bls.gov/spotlight/2017/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future/pdf/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future.pdf

Fitzgerald, G. J. (2008). Chemical warfare and medical response during World War I. *American Journal of Public Health, 98*(4), 611–625. https://doi.org/10.2105/ajph.2007.111930

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry, 12*(2), 219–245.

Forman, J., Gubbins, E. J., Villanueva, M., Massicotte, C., Callahan, C., & Tofel-Grehl, C. (2015). National survey of STEM high schools' curricular and instructional strategies and practices. *NCSSS Journal, 20*(1), 8–19. https://files.eric.ed.gov/fulltext/EJ1093051.pdf

Freeman, S., Eddy, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M. (2014, June). Active learning boosts performance in STEM courses. *Proceedings of the National Academy of Sciences, 111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Gillespie, N. (2015). The backbone of STEM teaching. *Phi Delta Kappan, 96*(6), 38–44. https://doi.org/10.1177/0031721715575298

Gorman, S., Durmowicz, M., Roskes, E., & Slattery, S. (2010). Women in the academy: Female leadership in STEM education and the evolution of a mentoring web. *Forum on Public Policy, 2010*(2), 1–21. http://files.eric.ed.gov/fulltext/EJ903573.pdf

Graf, N., Fry, R., & Funk, C. (2018, January 9). *7 facts about the STEM workforce.* Pew Research Center. http://www.pewresearch.org/fact-tank/2018/01/09/7-facts-about-the-stem-workforce/

Gunn, H., Hunter, H., & Haas, B. (2012). Problem based learning in physiotherapy education: A practice perspective. *Physiotherapy*, *98*(4), 335–340. https://doi.org/10.1016 /j.physio.2011.05.005

Guzey, S. S., Moore, T. J., & Harwell, M. (2016). Building up STEM: An analysis of teacher-developed engineering design-based STEM integration curricular materials. *Journal of Pre-College Engineering Education Research, 6*(1), Article 2. https://doi.org/10.7771/2157-9288.1129

Guzey, S. S., Moore, T. J., Harwell, M., & Moreno, M. (2016). STEM integration in middle school life science: Student learning and attitudes. *Journal of Science Education and Technology, 25*(4), 550–560. https://doi.org/10.1007/s10956-016-9612-x

Hanif, S., Wijaya, A., Winarno, C. (2019). Enhancing Students' Creativity through STEM Project-Based Learning. *Journal of Science Learning, 2*(2), 50-57.

Hanson, S. (2009). *Swimming against the tide: African American girls and science education*. Temple University Press.

Haring, M. (1999). The case of a conceptual base for minority mentoring programs. *Peabody Journal of Education, 74*(2), 5–14. https://doi.org/10.1207/s15327930pje7402_2

Haug, B. (2014). Inquiry-based science: Turning teachable moments into learnable moments. *Journal of Science Teacher Education, 25,* 79–96. https://doi.org/10.1007/s10972-013-9375-7

Hendee, C. (2015, October 9). Ex Lockheed CEO: Here's what we need from our schools. *Denver Business Journal.* http://www.bizjournals.com/denver/blog/broadway_17th/2015/10/7-stem-education-questions-for-ex-lockheed-martin.html

Henriksen, Danah (2014) "Full STEAM Ahead: Creativity in Excellent STEM Teaching Practices," The STEAM Journal: Vol. 1: Iss. 2, Article 15. DOI: 10.5642/steam.20140102.15

Herold, J. (1974). Sputnik in American education: A history and reappraisal. *McGill Journal of Education, 9*(2), 143–164. https://mje.mcgill.ca/article/view/6971

Hossain, M., & Robinson, M. (2012). How to motivate U.S. students to pursue STEM (Science, Technology, Engineering and Mathematics) careers. *US-China Education Review A, 4*(2012), 442–451. https://files.eric.ed.gov/fulltext/ED533548.pdf

Hom, E. (2014, February). What is STEM education? Live Science. https://www.livescience.com/43296-what-is-stem-education.html

Hunzicker, J. (2017). From teacher to teacher leader: A conceptual model. *International Journal of Teacher Leadership, 8*(2), 1–19. https://files.eric.ed.gov/fulltext/EJ1169800.pdf

Hwang, J., & Taylor, J. C. (2016). Stemming on STEM: A STEM education framework for students with disabilities. *Journal of Science Education for Students with Disabilities, 19*(1), Article 4. https://doi.org/10.14448/jsesd.09.0003

Isabelle, A. D. (2017). STEM is elementary: Challenges faced by elementary teachers in the era of the next generation science standards. *The Educational Forum, 81*(1), 83–91. https://doi.org/10.1080/00131725.2016.1242678

Johnson, J. (2019). *Anniversary of powered flight: The right move for the Wright brothers.* Joint Base San Antonio. https://www.jbsa.mil/News/News/Article/2041818/anniversary-of-powered-flight-the-right-move-for-the-wright-brothers/

Jolly, A. (2013, March 24). *The 10 essential STEM teaching practices.* Middle Web: All about the Middle Grades. https://www.middleweb.com/6624/10-stem-teaching-practices/

Jolly, A. (2014, June 17). Six characteristics of a great STEM lesson. *Education Week Teacher*. https://www.edweek.org/tm/articles/2014/06/17/ctq_Jolly_stem.html

Karau, M. D. (2017). Submarines and submarine warfare. *International Encyclopedia of the First World War*. https://encyclopedia.1914-1918-online.net/article/submarines_and_submarine_warfare

Keitch, C., & Blair, J. (2017, December 7). *What impact did the first world war have on aircraft and aerial welfare?* Imperial War Museums. https://www.iwm.org.uk/learning/resources/what-impact-did-the-first-world-war-have-on-aircraft-and-aerial-warfare

Kelley, T. (2010). Staking the claim for the “T” in STEM. *The Journal of Technology Studies, 36*(1), 2–11. https://files.eric.ed.gov/fulltext/EJ906155.pdf

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *IJ STEM Ed*, *3*, 11. https://doi.org/10.1186/s40594-016-0046-z

Kennedy, T., & Odell, M. (2014). Engaging students in STEM education. *Science Education International*, *25*(3), 246–258. https://files.eric.ed.gov/fulltext/EJ1044508.pdf

Kim, H., & Scantlebury, K. (2013). Being "chill" with teachers and "frozen" by peers in science: Overcoming social and educational barriers in a learning community. *Cultural Studies of Science Education, 8,* 673–682. https://doi.org/10.1007/s11422-013-9507-6

Klein, E. J., Taylor, M., Munakata, M., Trabona, K., Rahman, Z., & McManus, J. (2018). Navigating teacher leaders' complex relationships using a distributed leadership framework. *Teacher Education Quarterly*, *45*(2), 89–112. https://files.eric.ed.gov/fulltext/EJ1175531.pdf

Kose, B. W. (2007). Principal leadership for social justice: Uncovering the content of teacher professional development. *Journal of School Leadership*, *17*(3), 276–312. https://doi.org/10.1177/105268460701700302

Kraus, R. (2008). *Overcoming the difficulties of inquiry-based teaching through the use of coaching* (Doctoral dissertation, Harvard University).

Krishnamurthi, A., Bevan, B., Rinehart, J., & Coulon, V. (2013). What afterschool stem does best. *Afterschool Matters*, *18,* 42–49.

Krishnamurthi, A., Ottinger, R., Topol, T. (2009). The power of afterschool and summer learning for student success. *Expanding Minds and Opportunities*, 132–139.

LaForce, M., Noble, E., King, H., Century, J., Blackwell, C., Holt, S., . . . Loo, S. (2016). The eight essential elements of inclusive STEM high schools. *International Journal of STEM Education, 3,* Article 21. https://doi.org/10.1186/s40594-016-0054-z

Lansat, M., & Feloni, R. (2018, July 26). *Girl Scouts have gone from baking and sewing to cybersecurity and financial literacy.* Business Insider. https://www.businessinsider.com/girl-scouts-ceo-adds-stem-badges-2018-7

Larson, M. (2018). *Catalyzing change in high school mathematics: Initiating critical conversations.* National Council of Teachers of Mathematics.

Learning Liftoff. (2019). New reports: Students' ACT scores continue to decline in math. https://www.learningliftoff.com/students-act-scores-continue-to-decline-in-math/

Lichtman, M. (2013). *Qualitative research in education: A user's guide.* Sage.

Lipton, L., & Wellman, B. (2012). *Got data? Now what?: Creating and leading cultures of inquiry.* Solution Tree.

Littrell, P., Billingsley, B., & Cross, L. (1994). The effects of principal support on special and general educators' stress, job satisfaction, school commitment, health, and intent to stay in teaching. *Journal of Science Teacher Education, 15,* 297–310. https://doi.org/10.1177/074193259401500505

Lynch, M. (2017, November 20). *STEM Education is about hands on experiences.* The Edvocate. Retrieved from: https://www.theedadvocate.org/stem-education-hands-experiences/

Margot, K. C., & Kettler, T. (2019). Teachers' perceptions of STEM integration and education: A systematic literature review. *International Journal of STEM Education, 6*(1), 1–16. https://doi.org/10.1186/s40594-018-0151-2

Marshall, S. (2010). Re-imagining specialized STEM academies. *Roeper Review, 32,* 48–60.

McGee, R. (2013). High-achieving Black students, biculturalism, and out-of-school STEM learning experiences: Exploring some unintended consequences. *Journal of Urban Mathematics Education, 6*(2), 20–41. https://files.eric.ed.gov/fulltext/EJ1085783.pdf

Merriam, S. B. (2002). *Intro to qualitative research.* John Wiley and Sons.

Merriam, S. B., & Tisdell, E. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.

Milcrom-Elcott, T. (2020). *Four things that you need to know about STEM education in 2020*. Forbes. https://www.forbes.com/sites/taliamilgromelcott/2020/01/13/four-things-you-need-to-know-about-stem-and-education-for-2020/#d6efeea3aac8

Miller, B. (1995). The role of rural schools in rural community development. *Eric Digest.* https://www.ericdigests.org/1996-1/rural.htm

Modi, K., Schoenberg, J., & Salmond, K. (2012). *Generation STEM: What Girls Say about Science, Technology, Math, and Engineering*. http://www.girlscouts.org/research/pdf/generation_stem_full_report.pdf

Moore, T. J., & Smith, K. A. (2014). Advancing the state of the art of STEM integration. *Journal of STEM Education, 15*(1), 5–10.

http://personal.cege.umn.edu/~smith/docs/Moore-Smith-JSTEMEd-GuestEditorialF.pdf

Morrison, J. (2008). Individual inquiry investigations in an elementary science methods course. *Journal of Science Teacher Education*, *19*, 117–134. https://doi.org/10.1007/s10972-007-9086-z

Mosatche, H., Matloff-Nieves, S., Kekelis, L., & Lawner, E. (2013). Effective STEM programs for adolescent girls. *Afterschool Matters, 17*, 17–25.

Moss, J. (2016). *Where are all the teachers of color?* Harvard Ed. Magazine. https://www.gse.harvard.edu/news/ed/16/05/where-are-all-teachers-color

Myers, A., & Berkowicz, J. (2015). *The STEM shift: A guide for school leaders*. Corwin.

The Nation's Report Card. (2019). *NAEP Report card: mathematics.* The Nation's Report Card. https://www.nationsreportcard.gov/mathematics?grade=4

Nedland, B. (2012). *EnvironMentors: A mixed methods study of underrepresented youth pursuing environmentally focused STEM career paths* (Master's thesis, Colorado State University). http://hdl.handle.net/10217/71932

Nickerson, S. D., Vaugh, M., Lamb, L., Ross, D., Philipp, R., LaRochelle, R., & Williams, K. S. (2018). A model for selecting exemplary mathematics and science teacher leaders. *Journal of School Administration Research and Development*, *3*(1), 67–73.

NPR. (2009). *Black scientist's path to success was often lonely.* [Interview with Shirley Ann Jackson]. https://www.npr.org/templates/story/story.php?storyId=101412303

Patton, S. (2020). *Elementary school teacher's beliefs, organizational change, and STEM implementation: Factors impacting teacher leadership* (Doctoral dissertation, Kennesaw State University). https://digitalcommons.kennesaw.edu/teachleaddoc_etd/39

Peters-Burton, E. E., & Johnson, T. (2018). Cross-case analysis of engineering education experiences in inclusive STEM-focused high schools in the United States. *International Journal of Education in Mathematics, Science and Technology, 6*(4), 320–342. https://doi.org/10.18404/ijemst.440335

Pierpont, K. (2005). A dream realized. *Teaching Pre K-8, 36*(3), 36–39.

Powell, A. (2007). How sputnik changed U.S. education. *The Harvard Gazette.* https://news.harvard.edu/gazette/story/2007/10/how-sputnik-changed-u-s-education/

Pringle, J., & Peters, R. (1975). Effects of world war II on the development of knowledge in the biological sciences (and discussion). *Proceedings of the Royal Society of London, 342*(1631), 537–548. https://www.jstor.org/stable/78752

Public Schools First NC. (2020). *The facts on rural schools.* https://www.publicschoolsfirstnc.org/wp-content/uploads/2020/03/Facts-on-Rural-Schools-3.4.20.pdf

Ramirez, A. (2013). *Creativity is the secret sauce in STEM.* Edutopia. https://www.edutopia.org/blog/creativity-secret-sauce-in-stem-ainissa-ramirez

Rath, T. (2008). *Strengths based leadership: Great leaders, teams, and why people follow.* Gallup Press.

Rice, L., Barth, J., Guadagno, R., Smith, G., & McCallum, D. (2013). The role of social support in students' perceived abilities and attitudes toward math and science. *Journal of Youth and Adolescence, 42*(7), 1028–1040. https://doi.org/10.1007/s10964-012-9801-8

Riedinger, K., & Taylor, A. (2016). I could see myself as a scientist. *Afterschool Matters, 23*, 1–7. https://eric.ed.gov/?id=EJ1095940

Ring, E. A., Dare, E. A., Crotty, E. A., & Roehrig, G. H. (2017). The evolution of teacher conceptions of STEM education throughout an intensive professional development experience. *Journal of Science Teacher Education, 28*(5), 444–467. https://doi.org/10.1080/1046560X.2017.1356671

Sahin, A., Ayar, M., & Adiguzel, T. (2014). STEM-related after-school program activities and associated outcomes on student learning. *Educational Sciences: Theory and Practice*, 14(1), 309–322.

Sanders, M. (2009). STEM, STEM Education, STEMMANIA. *The Technology Teacher, 68*(4), 20–26. https://eric.ed.gov/?id=EJ821633

Schultz, P. W., Hernandez, P. R., Woodcock, A., Estrada, M., Chance, R. C., Aguilar, M., & Serpe, R. T. (2011). Patching the pipeline: Reducing educational disparities in the sciences through minority training programs. *Educational Evaluation and Policy Analysis, 33,* 95–114. https://doi.org/10.3102/0162373710392371

Schwantes, M. (2017, November 24). *Research says this required job skill will trump emotional intelligence by the year 2020.*

https://www.inc.com/marcelschwantes/study-you-will-need-this-top-job-skill-to-succeedin-age-of-robots-by-2020.html

Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education, 4*(13), 1–16. https://doi.org/10.1186/s40594-017-0068-1

Showalter, D., Hartman, S., Johnson, J., & Klein, B. (2019). *Why rural matters 2018-19, the time is now.* A Report of the Rural School and Community Trust. http://www.ruraledu.org/WhyRuralMatters.pdf

Slavit, D., Nelson, T., & Lesseig, K. (2016). The teachers' role in developing, opening, and nurturing an inclusive STEM-focused school. *International Journal of STEM Education, 3*(7), 1–17. https://doi.org/10.1186/s40594-016-0040-5

Smith, L., & Southerland, S. (2006). Reforming practice or modifying reforms?: Elementary teachers' response to the tools of reform. *Journal of Research in Science Teaching, 44*(3), 396–423. https://doi.org/10.1002/tea.20165

Stains, M., Harshman, J., Barker, M. K., Chasteen, S. V., Cole, R., DeChenne-Peters, S. E., . . . Young, A. M. (2018). Anatomy of STEM teaching in American universities: A snapshot from a large-scale observation study. *Science, 359*(6383), 1468–1470. https://doi.org/10.1126/science.aap8892

Sujeewa Vijayanthi Polgampala, A., Shen, H., & Huang, F. (2017). STEM teacher education and professional development and training: Challenges and trends.

American Journal of Applied Psychology, 6(5), 93–97. https://doi.org/10.11648/j.ajap.20170605.12

Teacher Leadership Exploratory Consortium. (2011). *Teacher leader model standards.* Author. http://www.teacherleaderstandards.org/downloads/TLS_Brochure.pdf

Tellis, W. (1997). Application of a case study methodology. *The Qualitative Report, 3*(3), 1–19. https://nsuworks.nova.edu/tqr/vol3/iss3/1

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., . . . Depaepe, F (2018). Integrated STEM education: A systematic review of instructional practices in secondary education. *European Journal of STEM Education*, *3*(1), Article 2. https://doi.org/10.20897/ejsteme/85525

Tran, D. (2015). *If you want better collaboration around STEM, build infrastructure. Improving quality of STEM instruction.* https://www.advanc-ed.org/source/if-you-want-better-collaboration-around-stem-build-infrastructure

Trueman, C. N. (2015, March 31). *Gas masks in World War One.* The History Learning Site. https://www.historylearningsite.co.uk/world-war-one/the-western-front-in-world-war-one/gas-masks-in-world-war-one/#:~:text=Gas%20masks%20used%20in%20World,mere%20thought%20seemed%20too%20shocking

U.S. Bureau of Labor Statistics. (2017). *Employment in STEM occupations.* https://www.bls.gov/emp/tables/stem-employment.htm

U.S. Department of Education. (2020). *Science, Technology, Engineering, and Math, including Computer Science.* U.S. Department of Education. https://www.ed.gov/stem

Wassell, B. A., Hawrylak, M. F., & Scantlebury, K. (2015). Barriers, resources, frustrations, and empathy: Teachers' expectations for family involvement for Latino/a ELL students in urban STEM classrooms. *Urban Education, 52*(10), 1233–1254. https://doi.org/10.1177/0042085915602539

Wee Teo, T. (2012). Building Potemkin schools: Science curriculum reform in a STEM school. *Journal of Curriculum Studies, 44*(5), 659–678. https://doi.org/10.1080/00220272.2012.689356

Wenner, J. (2017). Urban elementary science teacher leaders: Responsibilities, supports, and needs. *Science Education, 25*(2), 117–125. https://files.eric.ed.gov/fulltext/EJ1132097.pdf

White, D. (2014). What is STEM education and why is it important? *Florida Association of Educators Journal, 1*(14), 1–9.

White, J. L., Altschuld, J. W., & Lee, Y.-F. (2006). Cultural dimensions in science, technology, engineering and mathematics: Implications for minority retention research. *Journal of Educational Research & Policy Studies, 6*(2), 41–59. https://files.eric.ed.gov/fulltext/EJ844652.pdf

Wilkerson, S., & Haden, C. (2014). Effective practices for evaluating STEM out-of-school time programs. *After School Matters, 24,* 10–19. https://files.eric.ed.gov/fulltext/EJ1021960.pdf

Wolcott, H. (1994). *Transforming qualitative data: Description, analysis, and interpretation.* Sage.

Wong, A. (2019). *The U.S. teaching population is getting bigger, and more female.* The Atlantic. https://www.theatlantic.com/education/archive/2019/02/the-explosion-of-women-teachers/582622/

Wright, J. (2017). *The Rise of STEM Majors are accelerating in every state, just as humanities degrees are declining*. EMSI. https://www.economicmodeling.com/2017/09/01/stem-majors-accelerating-every-state-just-humanities-degrees-declining/

Wynn, T., & Harris, J. (2012). Toward a STEM + arts curriculum: Creating the teacher team. *Art Education*, *65*(5), 42–47. https://doi.org/10.1080/00043125.2012.11519191

Yuen, T. T., Boecking, M., Stone, J., Tiger, E. P., Gomez, A., Guillen, A., & Arreguin, A. (2014). Group tasks, activities, dynamics, and interactions in collaborative robotics projects with elementary and middle school children. *Journal of STEM Education: Innovations and Research*, *15*(1), 39–45. https://eric.ed.gov/?id=EJ1034672

Yin, R. (2003). *Case study research: Design and methods* (3rd ed.). Sage.

York-Barr, A. J., & Duke, K. (2004). What do we know about teacher leadership?: Findings from two decades of scholarship. *Review of Educational Research*, *74*(3), 255–316. https://doi.org/10.3102/00346543074003255

Zimmerman, E. (2018, July 27). *The 4 C's of learning in a connected classroom.* Ed Tech. https://edtechmagazine.com/k12/article/2018/07/4-cs-learning-connected-classroom

APPENDIX A

IRB APPROVAL

UNC GREENSBORO

OFFICE OF RESEARCH INTEGRITY
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Federalwide Assurance (FWA) #216

To: Christy Bailey
Ed Ldrship and Cultural Found
cbailey@rock.k12.nc.us

From: UNCG IRB

Date: 5/01/2020

RE: Notice of IRB Exemption (modification)
Exemption Category: 2.Survey, interview, public observation,4.Secondary data/specimens
Study #: 19-0482
Study Title: STEM Teacher Leadership

This submission has been reviewed by the IRB and was determined to be exempt from further review according to the regulatory category cited above under 45 CFR 46.101(b).

Study Description:

This will be a qualitative case study of elementary school STEM (Science, Technology, Engineering, & Math) teacher leaders in a rural district in the Southeastern part of the nation. There is limited research available about how STEM teachers work as school leaders. The Teacher Leader Model Standards (2011) will be utilized as an analytical framework for exploring what STEM teacher leader practices are. STEM teacher leaders will also be studied for how they enact the pedagogical practices of creativity, collaboration, inquiry , and reflection.
Modification Information:

- Participants who have already consented to participate in the study may be contacted to address follow-up questions. The follow-up questions are related to the original interview questions. That is, the follow-up questions will ask the participant to repeat or talk more about items covered in the original interview questions. In some cases when the interviews were conducted remotely, technical difficulties occurred that made the interviews difficult to hear. In other cases, the participant's response was worthy of further exploration within the boundaries of the original interview question.

Investigator's Responsibilities
Please be aware that any changes to your protocol must be reviewed by the IRB prior to being implemented. **Please utilize the the consent form/information sheet with the most recent version date when enrolling participants**. The IRB will maintain records for this study for three years from the date of the original determination of exempt status.

Please be aware that valid human subjects training and signed statements of confidentiality for all members of research team need to be kept on file with the lead investigator. Please note that you will also need to remain in compliance with the university "Access To and Retention of Research Data" Policy which can be found at http://policy.uncg.edu/university-policies/research_data/.

APPENDIX B

INFORMED CONSENT FORM

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO CONSENT TO ACT AS A HUMAN PARTICIPANT

Project Title: STEM Teacher Leadership
Principal Investigator: Christy Ann Bailey
Faculty Advisor: Dr. Carl Lashley

Participant Name: ________________________________

What are some general things you should know about research studies?

You are being asked to take part in a research study. Your participation in the study is voluntary. You may choose not to join, or you may withdraw your consent to be in the study, for any reason, without penalty. Research studies are designed to obtain new knowledge to help people in the future. There may not be any direct benefit to you for being in the research study. There also may be risks to being in research studies. If you choose not to be in the study or leave the study before it is done, it will not affect your relationship with the researcher or the University of North Carolina at Greensboro. Details about this study are discussed in this consent form. It is important that you understand this information so that you can make an informed choice about being in this research study.

You will be given a copy of this consent form. If you have any questions about this study at any time, please feel free to ask the researchers named in this consent form. Their contact information is below.

What is the study about?
This is a research project, and your participation is voluntary. The purpose of the study is to learn more about the experiences and practices of a STEM teacher leader.

Why are you asking me?
You are being asked to participate in this study because the district office staff has identified you as a committed STEM teacher leader in an elementary classroom.

What will you ask me to do if I agree to be in the study?
Participants are being asked to complete an approximately 60 to 90 one on one interview and a follow up focus group interview for about 60 minutes with the principal investigator. Participants will be asked to submit a STEM artifact, such as, photographs of STEM activities, lesson plans, and academic data, such as, assessment data. All student identifiers should be removed. During this interview, you will be asked questions about your experience and practices as a STEM teacher leader.

What are the risks to me?
Since STEM teacher leaders are limited to a select number of teachers at a school there is a risk that the participant could have a concern about the breach of confidentiality. I would describe this risk as “infrequent.” It is also unlikely that the nature

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO CONSENT TO ACT AS A HUMAN PARTICIPANT

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What is the study about?
This is a research project, and your participation is voluntary. The purpose of the study is to learn more about the experiences and practices of a STEM teacher leader.

Why are you asking me?
You are being asked to participate in this study because the district office staff has identified you as a committed STEM teacher leader in an elementary classroom.

What will you ask me to do if I agree to be in the study?
Participants are being asked to complete an approximately 60 to 90 one on one interview and a follow up focus group interview for about 60 minutes with the principal investigator. Participants will be asked to submit a STEM artifact, such as, photographs of STEM activities, lesson plans, and academic data, such as, assessment data. All student identifiers should be removed. During this interview, you will be asked questions about your experience and practices as a STEM teacher leader.

What are the risks to me?
Since STEM teacher leaders are limited to a select number of teachers at a school there is a risk that the participant could have a concern about the breach of confidentiality. I would describe this risk as “infrequent.” It is also unlikely that the nature

of these interview content about being a STEM leader would enter sensitive material. The process of minimizing this risk will be outlined in the consent form and member check process for participants.

This study will also include a focus group meeting. During this time, participants will include the social interaction between the participation, as this could be a risk. Teachers will have the opportunity to share their personal experiences and opinions with each other. The individual participant responses could be like minded or disconnected. The focus group can create a safe, collaborative sharing space. This benefit outweighs the risk. To minimize risks, a major aspect of the protocol will be identifying the focus group norms for all members to commit to during the study.

If you have questions, want more information or have suggestions, please contact Christy Ann Bailey, principal Investigator by telephone at (336) 589-0611 or by email at camcbrid@uncg.edu or Dr. Carl Lashley, Faculty Advisor by phone at (336) 549- 9163 or by email at c_lashle@uncg.edu.

If you have any concerns about your rights, how you are being treated, concerns or complaints about this project or benefits or risks associated with being in this study, please contact the Office of Research Integrity at UNCG toll-free at (855)-251-2351.

Are there any benefits to *me* for taking part in this research study?
There are no benefits to you as a participant. A benefit to society maybe that school leaders and policy makers may gain a better understanding of supporting STEM teacher leaders and implementing STEM programs in schools. Another benefit is that teacher leaders may be more willing to commit to STEM implementation as a result of this study.

Will the interview be recorded?
Both the initial interview and any follow-up interview will be recorded digitally. Because your voice will be potentially identifiable by anyone who hears the recording, your confidentiality for things you say on the recording cannot be guaranteed although the researcher will try to limit access to the recording as described below in the confidentiality section. A paid transcriber will transcribe all interviews. The transcriber will sign an Acknowledgement of Confidentiality.

Confidentiality
All information obtained in this study is strictly confidential unless disclosure is required by law. Each person interviewed will be assigned a pseudonym and code so that raw data cannot be tied directly to a specific individual. The data will be stored in the UNCG Box account. The data key will be stored on a password-protected computer with an encrypted hard drive.

During the interview process, the data will be recorded on an iOS device that is encrypted with a passcode lock. The data will be transferred after the interview, within 24 hours, to the UNCG Box account to ensure data security and confidentiality. UNCG's

Box application meets all the university security standards.

Will I get paid for being in the study? Will it cost me anything?
No compensation will be provided to participate in the study.

What about new information/changes in the study?
If significant new information relating to the study becomes available which may relate to your willingness to continue to participate, this information will be provided to you."

APPENDIX C

INTERVIEW PROTOCOL

STEM Teacher Leadership Interview One-on-one Guide

*With this qualitative research, there may be follow-up questions to these initial question guide.

> **The interviews will be conducted as an open-ended conversation. The following questions are provided as a guide. The interviews will address these questions through informal interactions.**

Introduction, tell a short story about the location. School, or an object in the room to break the ice.

State names, date, and request permission to begin recording.

The purpose of this study is to better understand teachers who are leaders in STEM.

Demographic Questions

1. Name?
2. Current position?
3. How long in this position?
4. Education?

Grand Tour

Tell me about yourself

Describe your school experience.

How did you become interested in teaching?

Could you walk me through your career path to your current position?

Tell me about a typical day.

STEM Intro

Can you identify an event, person, or spark that created your interest in STEM?

Who do you ask your STEM teacher questions too?

What does STEM mean to you?

How do STEAM and STEM interact?

STEM Practice

Describe how you use inquiry methods in your classroom.

Can you give examples of collaboration activities in your classroom?

How do you embed real world problem solving in your classroom? Can you give examples?

Describe how creativity is used in your classroom.

How do you instill reflection into your STEM lessons?
STEM is messy and there is no exact blueprint. Can you give examples on how this is true or not true?

Describe how STEM can bridge achievement gaps?

How can you use STEM to meet diverse students?

Challenges

What are the challenges that keep teachers from using STEM?

How were you prepared as a teacher to teach multiple subjects together?

Describe the pre-teaching training that you received about STEM.

What type of STEM professional development have you received?

How do you purchase what you need for STEM lessons?

What support do you need in order to overcome these challenges?

STEM Leadership

How do you foster a collaborative culture to support teacher and student learning?

How do you access research to support teacher and student learning?

How do you promote professional development?

How do you facilitate improvement in instruction?

How do you use assessments and data?

How do you collaborate with families and the community?

How do you advocate for teachers and student learning?

New Elements/Topics

What is something that happened last week that contributed to your success?

What specific things happened this school year that has been a challenge for you?

What is the most rewarding part of your day?

We have talked about STEM practices and leadership. What else would you like to discuss?

What else is important to you about teaching?

Closing Question

Is there anything else that you would like to add that we have not discussed?